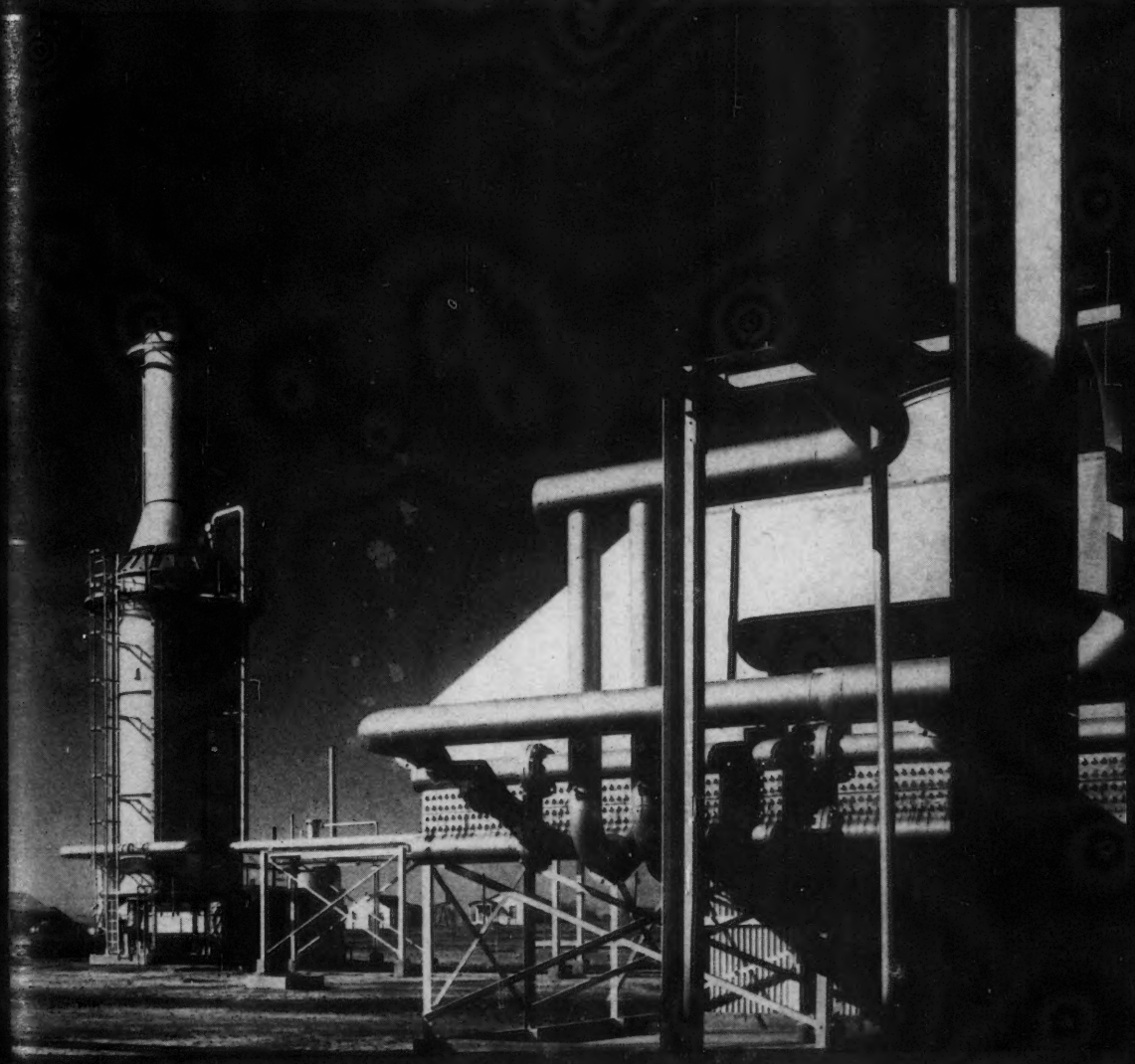
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



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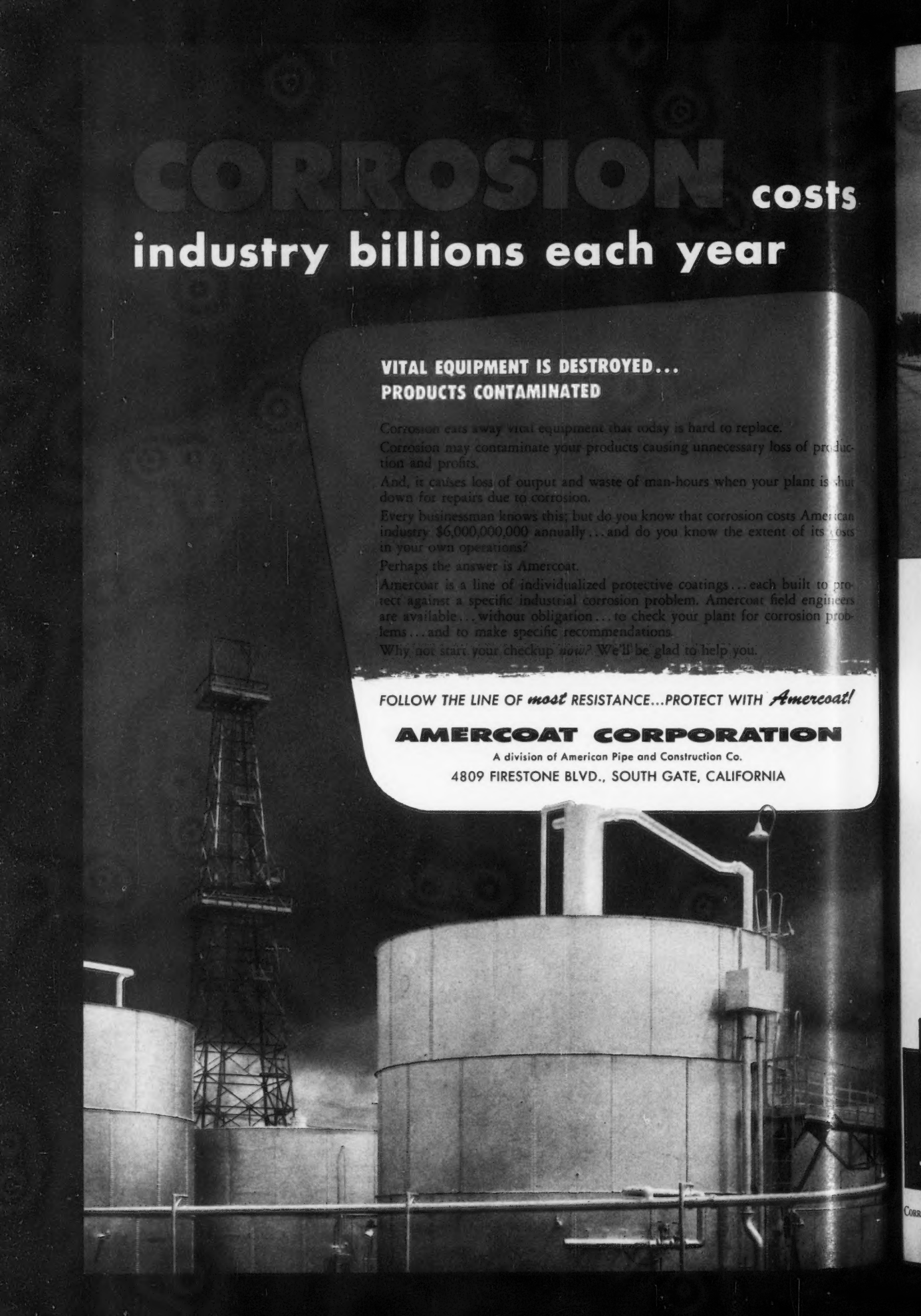
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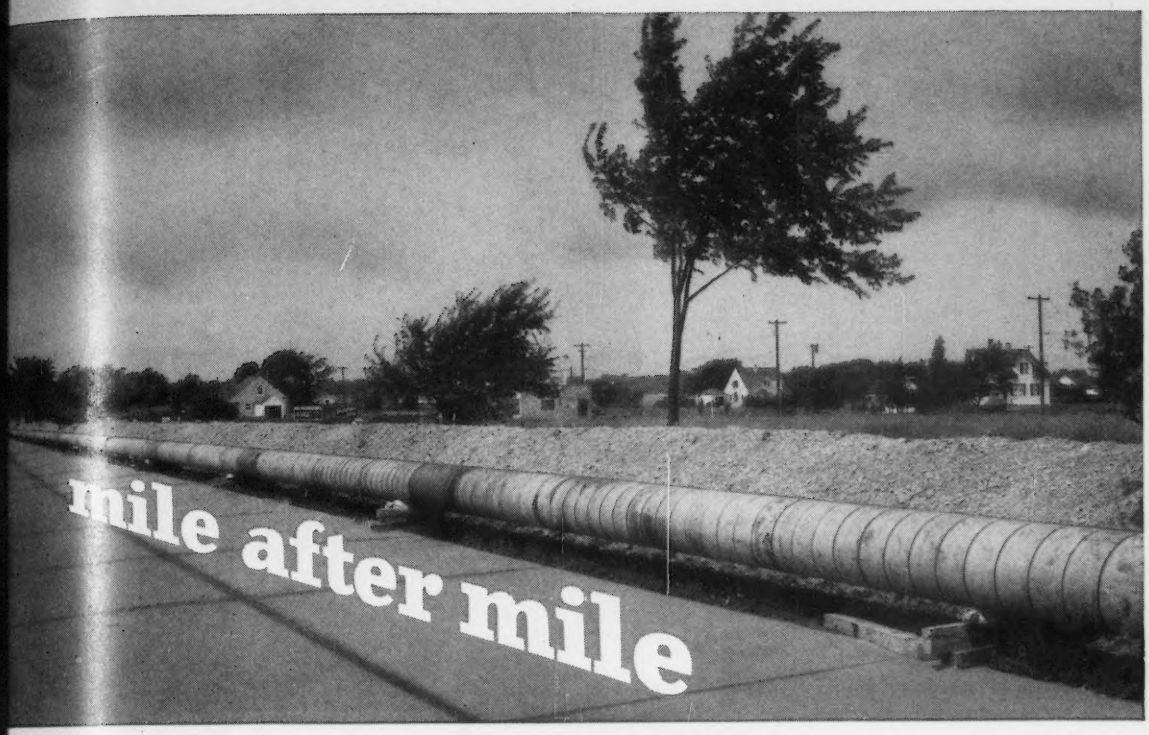

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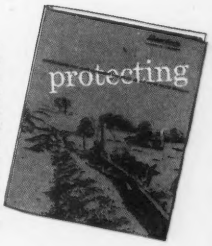

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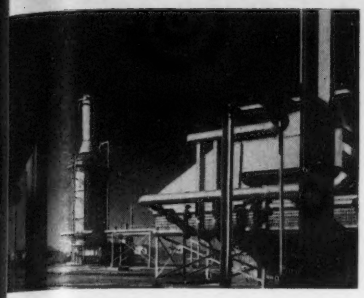

THIS MONTH'S COVER — Although surface temperatures on this oil heater stack range from 400° to 600° continuously, its protective coating based on a Corning Dow Silicone resin vehicle has an effective life of 18 months or more. Previously used paints lasted only a few days. This coating has become a standard specification in all Warren Petroleum Corporation plants. More information on this material is given in Topic of the Month, page 1, News Section, this issue. (Photo courtesy Warren Petroleum Corp. and Kansas Paint & Color Company.)

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Subscription: $7.50 per year to non-members; Member's dues $7.50, of which $3.75 are applied as subscription to CORROSION; Special rate, $3.50 per year for public libraries and libraries of educational institutions. Additional copies to members 50 cents, to non-members, 75 cents. Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds. Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion Is Indexed Regularly by Engineering Index.

Corrosion

devoted entirely to **CORROSION** *research and control*

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., as a permanent record of progress in corrosion control.

Vol. 8 **FEBRUARY, 1952** **No. 2**

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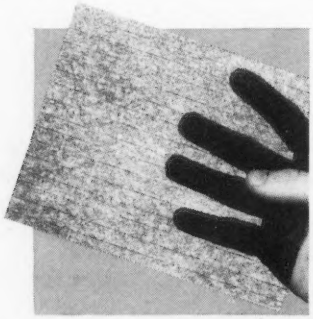

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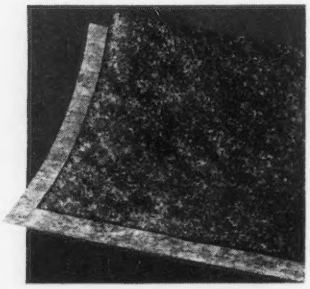

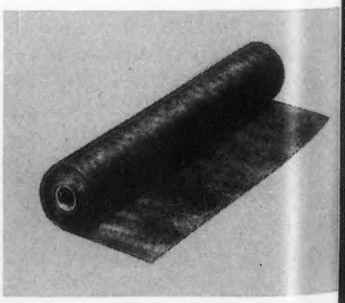

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The best aid to corrosion protection is GLASS!

ACTUAL FIELD EXPERIENCE PROVES that Fiberglas wraps give your pipelines maximum protection at low cost. These strong, tough materials can be applied up to 50% faster than ordinary wraps . . . with far fewer holidays per mile. Because fibrous glass is inert and inorganic, it will not rot . . . the wraps last for the life of the pipeline. Write us, on your letterhead, for full information and free samples. OWENS-CORNING FIBERGLAS CORPORATION, Dept. 53-B, Toledo 1, Ohio. Pacific Coast Division, Box 89, Santa Clara, California.

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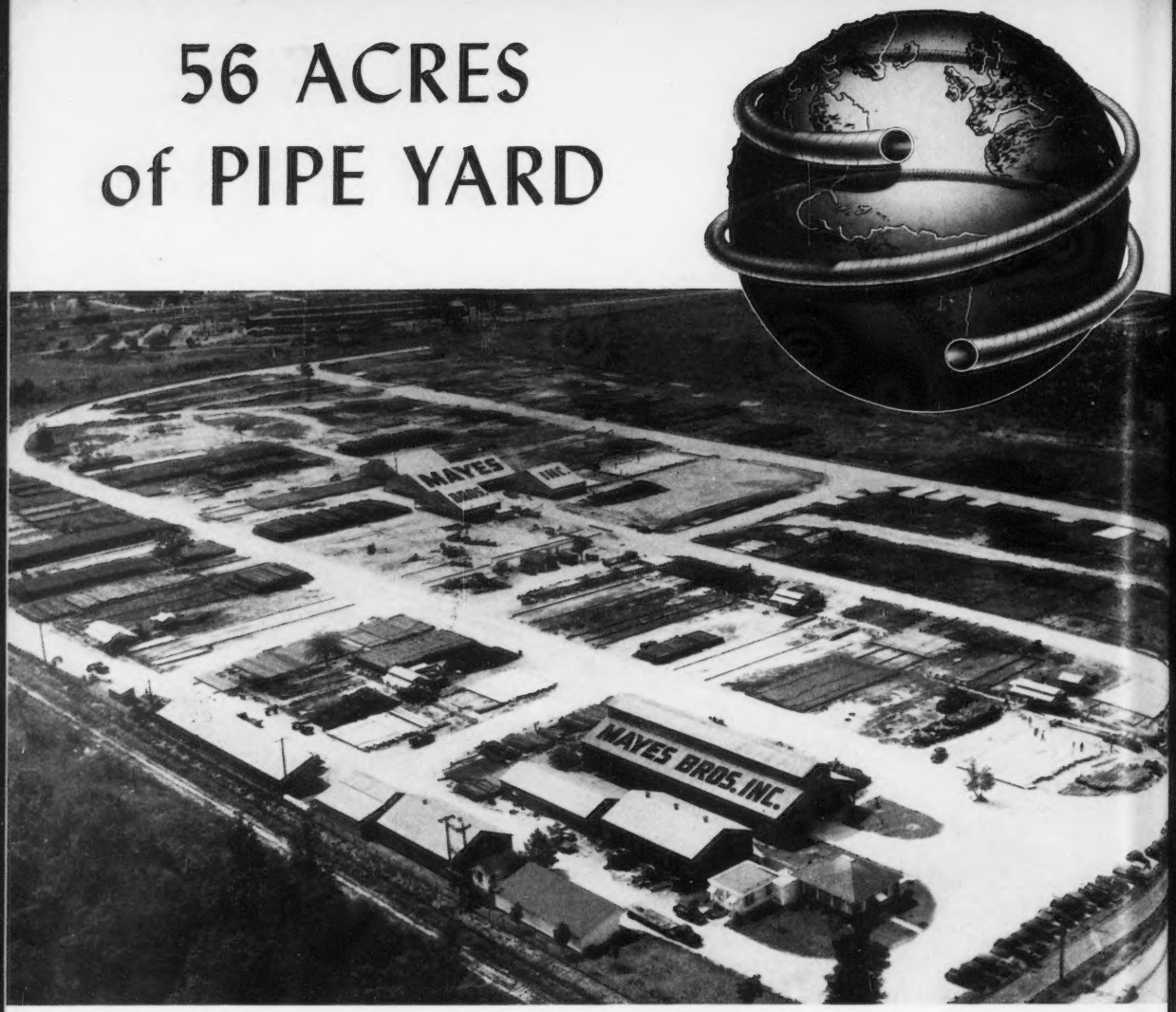

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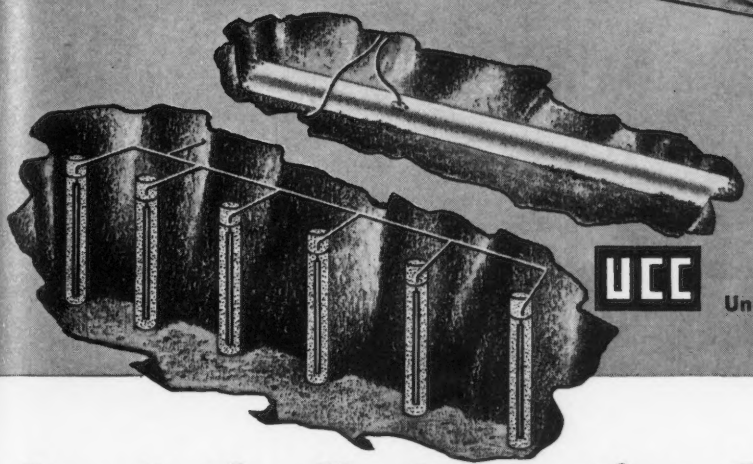

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Graphite electrodes are especially resistant to electrochemical oxidation.

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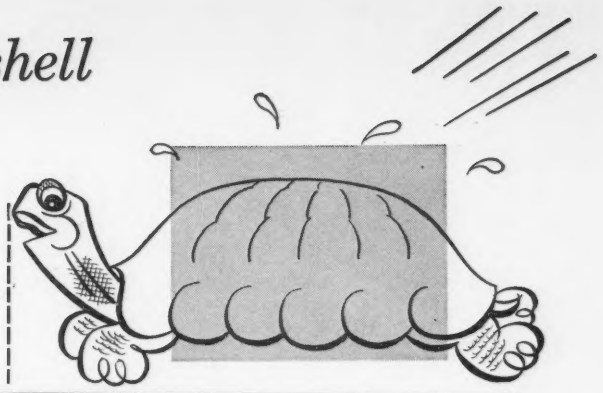

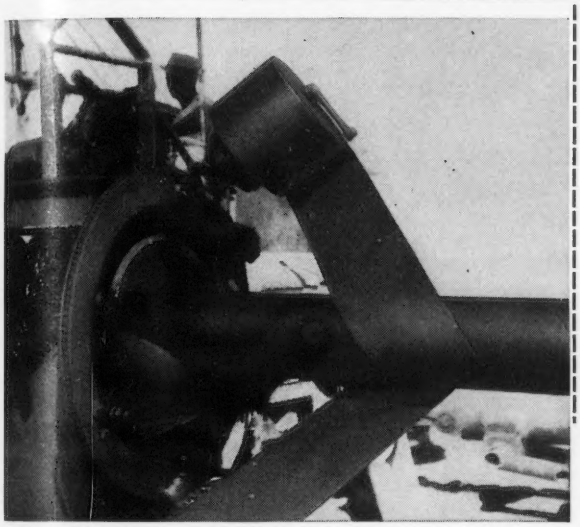

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Carbon	0.06
Sulfur	0.007

PHYSICAL CONSTANTS

Density, lb./cu. in.	0.307
Melting Range	2540°—2600°F.
Specific Heat (77°—212°F.)	0.109
Thermal Expansion Coefficient in./in. (100°—200°F.)	0.0000064
Thermal Conductivity (100°—212°F.) Btu/sq. ft./hr.°F./in.	104
Modulus of Elasticity in tension and compression, psi	31,000,000
in torsion, psi	11,000,000
Poisson's Ratio	0.29

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Figures shown are for standard cold-rolled sheet, hard. Variations will occur for different forms and tempers.

Tensile Strength	125,000 to 150,000 psi
Yield Strength (0.20% offset)	90,000 to 125,000 psi
Elongation in 2 in.	15% to 2%
Rockwell C. hardness	25 to 29

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Wire	Bar	Plate	Pipe
Rod	Angles	Sheet	Strip

Seamless and welded tubing

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Inconel is a thoroughly *practical* metal: workable, economical, produced in many convenient forms.

Inconel... and only Inconel... brings you *all* these desirable properties in a single alloy:

- **Unusually high resistance to chemical corrosives, both hot and cold, such as fatty and other organic acids, caustic alkalis at high temperatures, hot alkaline sulfides and strong chloride solutions.**
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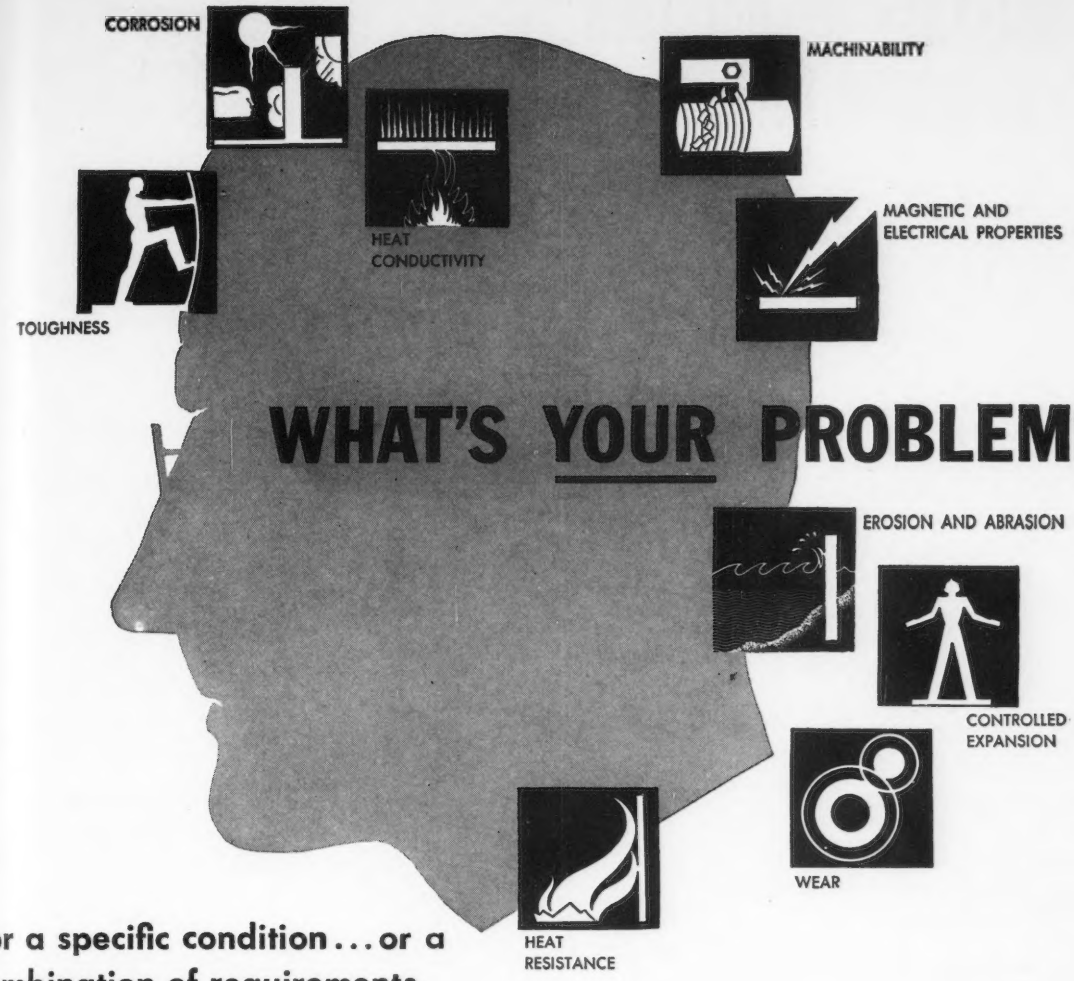

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NI-RESIST has good resistance to corrosive attacks of *acids*, *alkalies* and *salts*. In 5% sulfuric acid, for example, NI-RESIST outlasts cast iron 100 to 1.

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

919 Milam Bldg. Houston 2, Texas

Vol. 8 February, 1952 No. 2

Annual Awards by NACE

IN ORDER TO encourage further efforts in the fields of scientific research on corrosion processes and the control or prevention of corrosion as well as to recognize outstanding past contributions in these fields the Board of Directors of the National Association of Corrosion Engineers at its meeting in January, 1947, authorized the presentation annually of two Awards. It was decided the Awards should consist of appropriately worded, hand etched certificates which would be presented during ceremonies following the banquet during each Annual Conference and Exhibition of the Association.

The Awards Committee appointed by the board selected Willis Rodney Whitney and Frank Newman Speller as first recipients of the Awards. These men were regarded as so outstanding in their respective fields that in order to honor further their accomplishments the board decided to name the two awards after them. Thus the Willis Rodney Whitney Award as it is now known popularly, is the Science Award and the Frank Newman Speller Award is known as the Engineering Award.

As the membership of the association increased the procedure followed in naming an awards committee and selecting nominees for the Awards was recognized to be unsuitable. Therefore the board appointed a committe with Frank L. LaQue as chairman to devise a revised procedure for the organization of the awards committee and the selection of the recipients of the Awards. The procedure first proposed by this committee was revised three times before it was accepted by the board at its meeting in December, 1950.

In brief the revised procedure calls for the president of the association to appoint an awards committee consisting of at least six members of the association with the immediate past president of the association as its chairman. It provides that at least two but not more than four members of the committee shall be reappointed from the committee of the previous year but that no member shall serve on the committe for more than two years in succession. In regard to the selection of candidates to be considered for the Awards adequate provisions are made for the submission of names by individuals and local NACE Sections and Regions through regional chairmen.

The awards committee with Vance N. Jenkins as chairman, which recently completed its selection of the nominees for the 1952 Awards to be presented at the annual banquet during the Eighth Annual Conference and Exhibition of the Association in Galveston, March 10-14, was the first to function under the revised awards procedure. The committee recommends a few minor changes in procedure may be in order but that on the whole it is satisfactory.

In framing the revised procedure every effort was made to preserve the dignity of the Awards and to assure selection of nominees on the basis of their actual public contributions to the understanding of corrosion or its control rather than in recognition of their personal popularity. That achievement and popularity are not incompatible, however, is a fact well known to those fortunate enough to be acquainted personally with the men selected as recipients of the 1952 Awards.

Effectiveness of Cathodic Currents In Reducing Crevice Corrosion and Pitting Of Several Materials in Sea Water*

By THOMAS P. MAY and H. A. HUMBLE

IT IS WELL KNOWN that certain metals and alloys under appropriate conditions are susceptible to localized forms of corrosion which are commonly referred to as pitting and crevice corrosion. These forms of attack are frequently associated with metals and alloys which are likely to exhibit a passive condition in the particular environments. In some instances the local attack on a few small areas may be very rapid while at the same time the remaining bulk of the surface is unattacked. In other instances an initially rapid local attack may slow down with time and result in a mere loss of pleasing appearance in contrast to the destructive penetration of the progressive forms of attack. When the local sites of attack are located on boldly exposed surfaces, the corrosion is one of simple pitting. The term "crevice corrosion" is applied if the attack on small areas is associated with crevices or recesses where small concentration cells may develop.

This susceptibility to pitting or crevice corrosion restricts the number of applications where these passive materials would otherwise be useful. Accordingly, it was natural to inquire whether the application of cathodic protection would be practical as a means of eliminating or reducing pitting and crevice attack to an acceptable rate. This cannot be answered from experience in the cathodic protection of mild steel because of two important factors. First, the ratio of anode to cathode areas is different and, second, the cathode polarization characteristics are not necessarily the same for different materials.

When mild steel is immersed in sea water, it corrodes in a uniform manner without the development of excessive corrosion in local areas. From this it may be concluded that the surface of mild steel in sea water is approximately equally divided into local anode and cathode areas. Upon application of cathodic protection to this surface the applied current will flow principally to the local cathodes until they are polarized to the potential of the local anodes. This means that the applied current density on the local cathodes will be approximately twice the apparent current density on the steel which is being protected. The apparent applied current density which is required to protect mild steel in slowly moving sea water has been shown to be about 5 to 6 milliamperes per square foot of exposed steel surface. Accordingly the applied current density on the local

THOMAS P. MAY—A member of the Corrosion Engineering Section, The International Nickel Co., New York, he holds a B. Chem. Eng. and Ph. D. in physical chemistry from Catholic University of America, Washington, D. C. From 1939 to 1947 he was a member of the research staff of the Chemistry Division, Naval Research Laboratory, Washington, D. C., and was head of the Corrosion Section 1943-47. He joined International Nickel in 1947.

H. A. HUMBLE—Manager of Dow Chemical Company's cathodic protection sales, is a graduate of Duke University, with BA and MA degrees in chemistry. He joined Ethyl-Dow Chemical Company at Wilmington, North Carolina in 1933 leaving there in 1946 to go to Midland, Michigan to work on research and development of cathodic protection. From 1943 to 1946 he was production manager at Ethyl-Dow. A director of NACE, he is a member of the Electrochemical Society, the American Gas Association and the American Institute of Chemical Engineers.

Abstract

Crevice corrosion and pitting occur when chromium bearing stainless steels, chromium-nickel stainless steels and nickel are immersed in quiet sea water. The crevice corrosion on these materials is of the oxygen concentration cell type of attack. The pitting of these materials is usually severe in sea water. Monel in quiet sea water suffers slight, shallow pitting attack which usually is arrested before deep penetration occurs.

Experiments were conducted in sea water at Kure Beach, N. C., to determine the effectiveness of cathodic current in reducing these forms of corrosion. Test specimens were coupled to magnesium anodes with appropriate resistors in each circuit to control the currents. Potential measurements were made during the course of two runs of four and six months, respectively.

Cathodic current in quiet sea water reduces pitting and crevice corrosion on Types 410 and 430 stainless steels but its use is impractical because it causes severe blistering when the current is sufficient to eliminate the corrosion. This blistering is due to hydrogen which is formed on the cathode surfaces by the current. Hydrogen is also generated on mild steel surfaces but does not ordinarily produce blistering.

Cathodic currents effectively reduced these forms of corrosion on nickel, Monel and Types 302 and 316 stainless steels without the development of blisters even at 30 ma per sq. ft.

★ A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

cathodes would need be approximately 10 to 12 milliamperes per square foot of local cathodes.

When AISI Type 430 stainless steel (16-18 percent chromium) is immersed in sea water it suffers severe pitting and crevice corrosion in a very short time as illustrated in Figure 1 by the control specimen after 186 days in slowly moving sea water. In this instance the ratio of local cathode area to local anode area was approximately 50 to 1, and 98 percent of its area functioned as a cathode. Hence, if the local cathode area on Type 430 stainless steel has the same polarizing characteristics in sea water as the local cathodes on mild steel, this alloy, under the conditions of test on the illustrated specimen, would be expected to require about twice the current density for protection as that required for mild steel. This would be approximately 10 to 12 milliamperes per square foot in slowly moving sea water.

In the event local cathodes on the stainless steel require a higher current density for polarization than that required by the local cathodes on mild steel, the stainless would require a correspondingly higher apparent current density for protection.

Cathodic Protection Experiments

The materials in Table I were selected for exposure tests in quiet sea water at Kure Beach, N. C. The stainless steels and nickel are susceptible to serious crevice corrosion and aggressive pitting in quiet sea water although they usually exhibit noble potentials. Monel in quiet sea water develops shallow and broad pits which usually are not over a few mils in depth. This type of pitting is not structurally serious but it does mar the appearance of the alloy.

Specimens, ⅛ x 6 x 12 inches and ⅛ x 12 x 12 inches, were suspended in sea water on steel channel beams from which they were insulated by means of Bakelite washers and sleeves at the points of support.[1] These insulating washers, on both sides of each specimen at two bolt holes as illustrated by Wyche, et al.,[2] provided four crevices on each specimen. The total area of metal in the crevices was 4.73 square inches. Outside of the crevices the unshielded area was 143.8 square inches on the smaller specimens and 289.3 square inches on the larger ones, providing minimum cathode to anode area ratios of 30.4 and 61.2, respectively. Actually, all crevices were not identical because of slight variations in the flatness of the specimens around the mounting holes. The result was that the entire shielded area in the crevices on a given specimen was not always involved in the crevice corrosion which developed and the ratios of cathode area to anode area were usually larger than the minimum values.

Insulated copper wire was soldered to each speci-

TABLE I
Composition of Materials

Element	Stainless Steel—AISI Type 410	430	302	316	Nickel	Monel
C	0.088	0.069	0.111	0.048	0.03	0.12
Mn	.45	.22	1.16	1.85	.25	1.06
P	.015	.021	.026	.028	....	....
S	.016	.009	.021	.018	.005	.005
Si	.36	.50	.52	.54	.05	.17
Cr	13.01	17.00	18.55	17.41	....	....
Ni	.33	.32	9.94	12.56	99.43	65.62
Fe	Rem.	Rem.	Rem.	Rem.	.16	1.53
Cu	....	....	....	....	.05	31.47
Mo	....	....	....	2.27	....	....

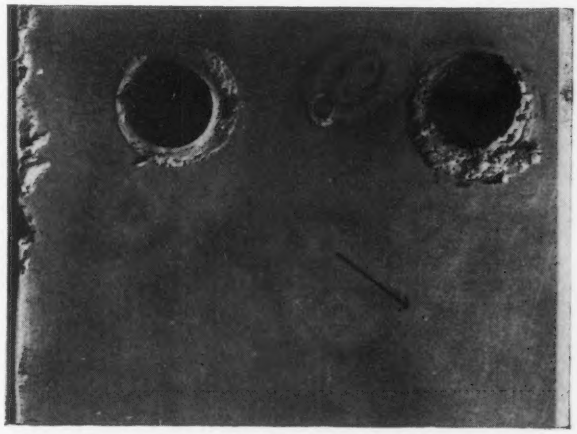

Figure 1—Crevice corrosion and pitting on Type 430 stainless steel in sea water 186 days without cathodic protection.

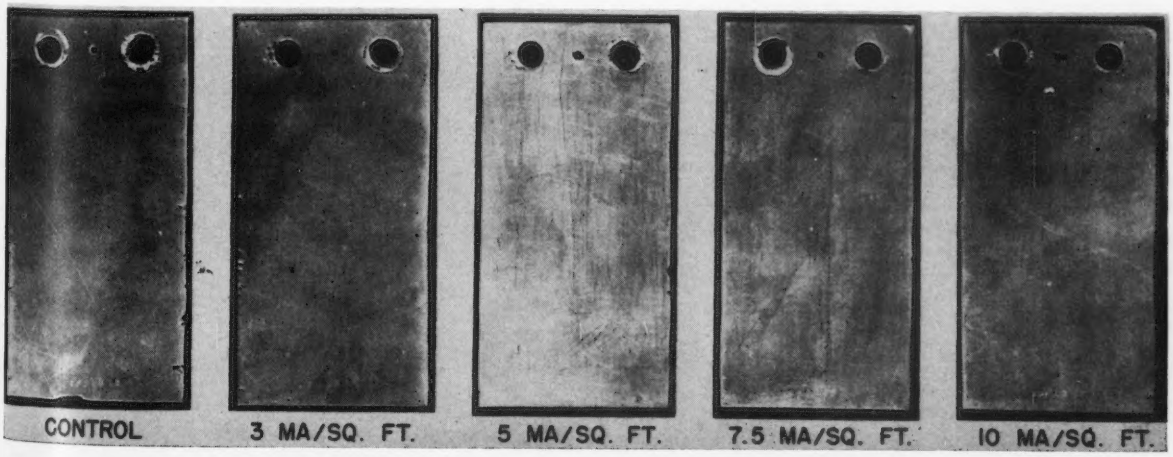

Figure 2—Final condition of specimens of Type 430 stainless steel vs cathodic current density after exposure for 186 days in quiet sea water.

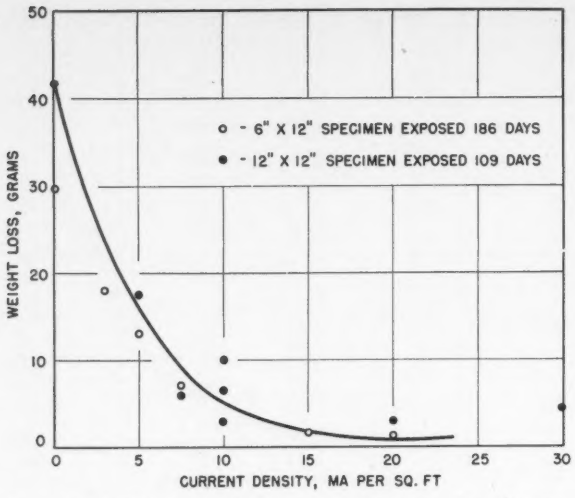

Figure 3—Weight loss vs cathodic current density on Type 430 stainless steel after exposure in quiet sea water.

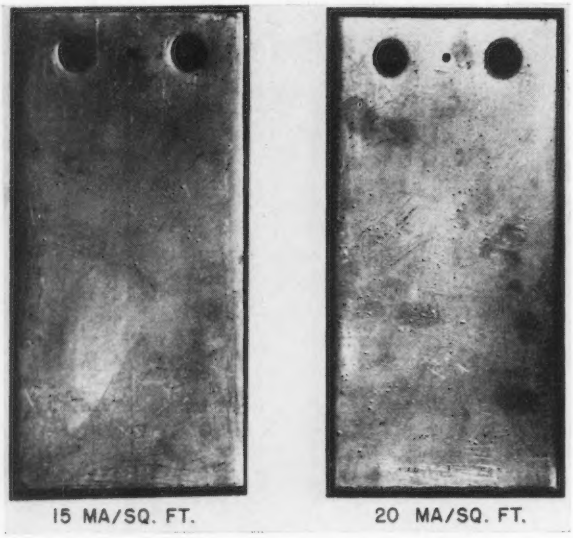

Figure 4—Hydrogen blisters formed in Type 430 stainless steel by cathodic currents during exposure in sea water for 186 days.

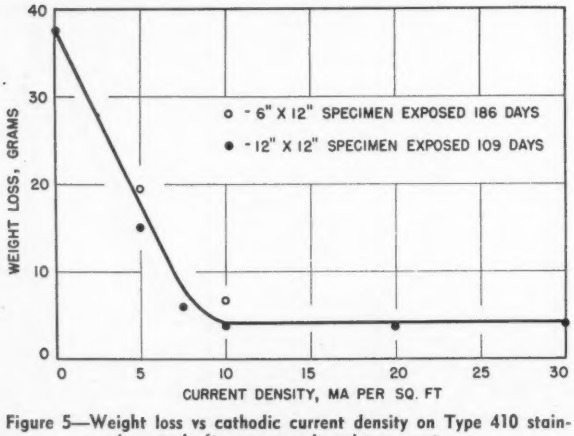

Figure 5—Weight loss vs cathodic current density on Type 410 stainless steel after exposure in quiet sea water.

men in the first test with the larger specimens. The wires served as connectors for potential measurements and for contacts to a magnesium anode. This anode, which furnished the current for these tests, was connected to a control panel to provide a separate variable resistor and a measuring shunt for each specimen that received current from the magnesium. The current controls provided adequate adjustments of individual currents without disturbing the remaining circuits.

12 x 12-inch specimens of each material were exposed at initial cathodic current densities of 0, 2, 3, 5, 7.5, and 10 milliamperes per square foot. After 29 days it became apparent that there would be little difference between the specimens at 2, 3 and 5 milliamperes per square foot. Accordingly, the specimens at 2 and 3 were changed to 20 and 30 milliamperes per square foot, respectively. The run was terminated after 109 days and specimens were inspected, cleaned and their weight losses determined.

Following these measurements a second exposure of 6 x 12-inch specimens was conducted for 186 days. Current densities were selected to confirm the earlier results or to provide additional data at current densities not used in the first run.

During the first run some difficulty was encountered with galvanic corrosion of the copper wires on the stainless steel specimens at the lower current densities. These were replaced with Type 302 wire, insulated with electrical insulating tape, as the copper wires failed. In the second run, the stainless steel wires were bolted to the specimens.

Potential measurements were made at frequent intervals using a saturated calomel reference electrode with a long salt bridge, the tip of which could be held against the specimens while the measurements were being made. Errors resulting from IR drop in the solution were reduced to a negligible level by this means.

Results

Well defined polarization curves were not obtained. At 20 and 30 ma per square foot all of the materials were polarized to at least —1100 mv referred to the saturated calomel electrode. At 10 ma per sq. ft. all materials would polarize 200 to 400 mv at different times during the test period but these potentials would not be sustained very long. Below 10 ma per sq. ft. the potentials varied with time in an irregular manner. This variation usually was within a 200-mv range. Except for occasional large variations the unpolarized specimens exhibited potentials of the order reported by LaQue and Cox.[3]

Generally speaking, the attack on specimens in the second run was not as severe as in the first run. This may have been due to one or more factors such as differences in the crevices, different corrosion conditions, and improvements in the electrical contacts in the second run. Nevertheless both runs indicated the same current densities for optimum effects on the different materials.

Type 430 Stainless Steel

This unprotected alloy suffered severe crevice attack and pitting as illustrated in Figure 1. The pit-

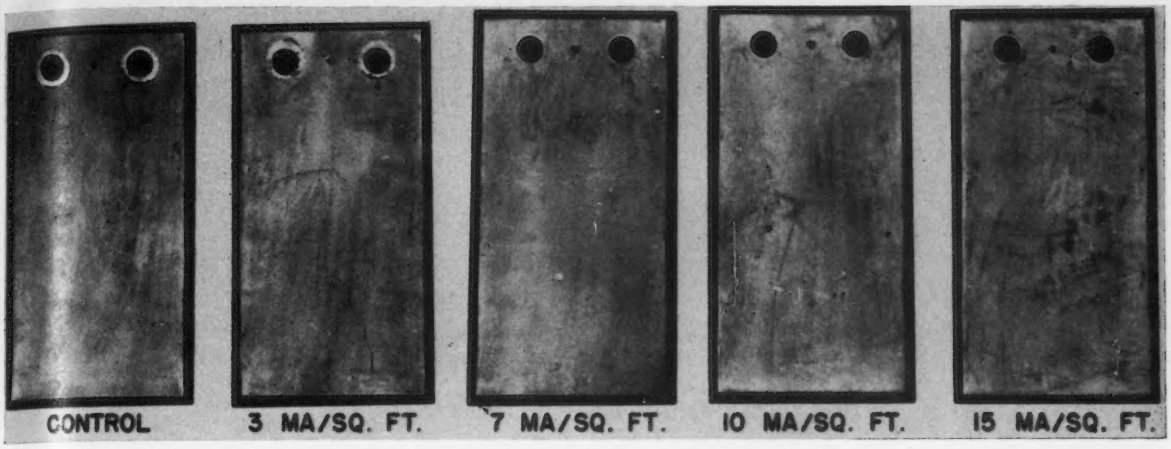

Figure 6—Final condition of specimens of Type 302 stainless steel vs cathodic current density after 186 days in quiet sea water.

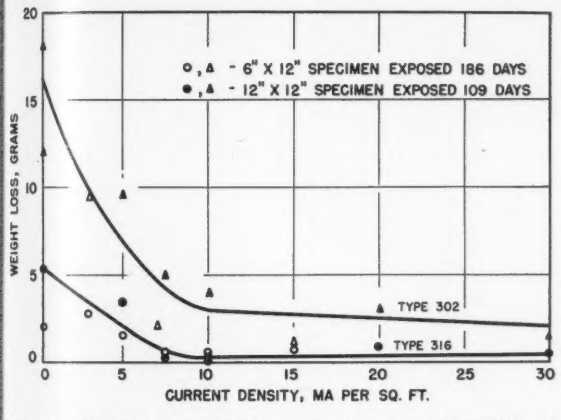

Figure 7—Weight loss vs cathodic current density on Types 302 and 316 stainless steels after exposure in quiet sea water.

ting was more predominant along the edges of the specimen but also appeared as extremely small pinholes on the surface. Upon probing the pinholes with a pointed needle, it was evident that severe corrosion frequently had occurred under a very thin layer of surface metal. The paper-thin character of this surface metal is evident. The arrow points to an undisturbed pit on the surface which was apparent only from the rust stain which was removed before the photograph was taken.

Increasing cathodic currents brought about a considerable reduction in pitting and crevice attack until 10 ma per sq. ft. was exceeded. Beyond this current density there was slight improvement in results. Some crevice attack was still observed at 15 ma per sq. ft. but none at 20 ma per sq. ft. This behavior is illustrated by the final condition of specimens in Figure 2 and is reflected in the weight losses plotted in Figure 3.

The improvement in performance of Type 430 stainless steel with cathodic protection was nullified by action of the cathodic currents which generated hydrogen and developed serious blisters as illustrated in Figure 4. This blistering was noted at current densities as low as 15 ma per sq. ft. but not at 10.

Type 410 Stainless Steel

The crevice corrosion and pitting on this alloy was quite similar to that on Type 430 stainless steel. This alloy also responded to cathodic protection in much the same manner. The reduction in pitting and crevice corrosion is reflected in the weight loss vs current density in Figure 5. As in the case with Type 430 stainless steel, the beneficial effects of cathodic currents on Type 410 are nullified by the formation of hydrogen blisters at useful levels of current density, namely, 10 ma per sq. ft. and higher.

Type 302 Stainless Steel

The unprotected controls suffered less from pitting than the Types 410 and 430 stainless steels. Cathodic protection also brought about virtually complete protection against these forms of corrosion at approximately 15 ma per sq. ft. as illustrated in Figure 6. It will also be noted that no hydrogen blistering resulted from cathodic current densities as high as 30 ma per square foot.

The reduction of crevice corrosion and pitting is also evident in the relation between weight loss and current density of Figure 7. The higher weight losses were obtained on the larger specimens which were exposed in the first and shorter exposure test during the early part of which the connecting wires were corroded away on several occasions and left the specimens without protection for several days.

Type 316 Stainless Steel

Except for exhibiting lesser intensity of attack, Type 316 responded to cathodic protection like Type 302 as shown in Figures 7 and 8. No serious corrosion was encountered at current densities of 15 ma per square foot. Blistering did not occur even at 30 ma per square foot.

Nickel

Some crevice attack and pitting continued to occur even at 10 ma per square foot as illustrated in Figure 9 but virtually complete protection was obtained at 20 ma per square foot. No hydrogen blisters developed even at 30 ma per square foot. Weight losses in Figure 10 support the observation of no attack at 20

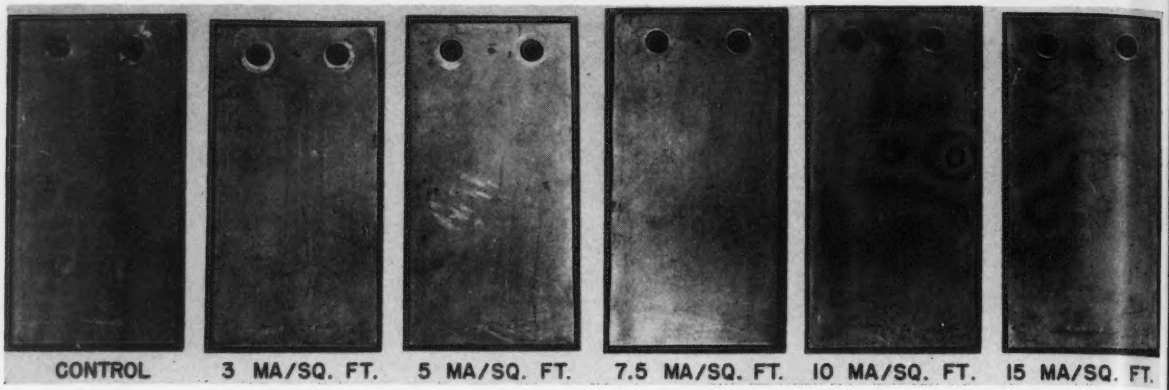

Figure 8—Final condition vs cathodic current density of Type 316 stainless steel after exposure in quiet sea water for 186 days.

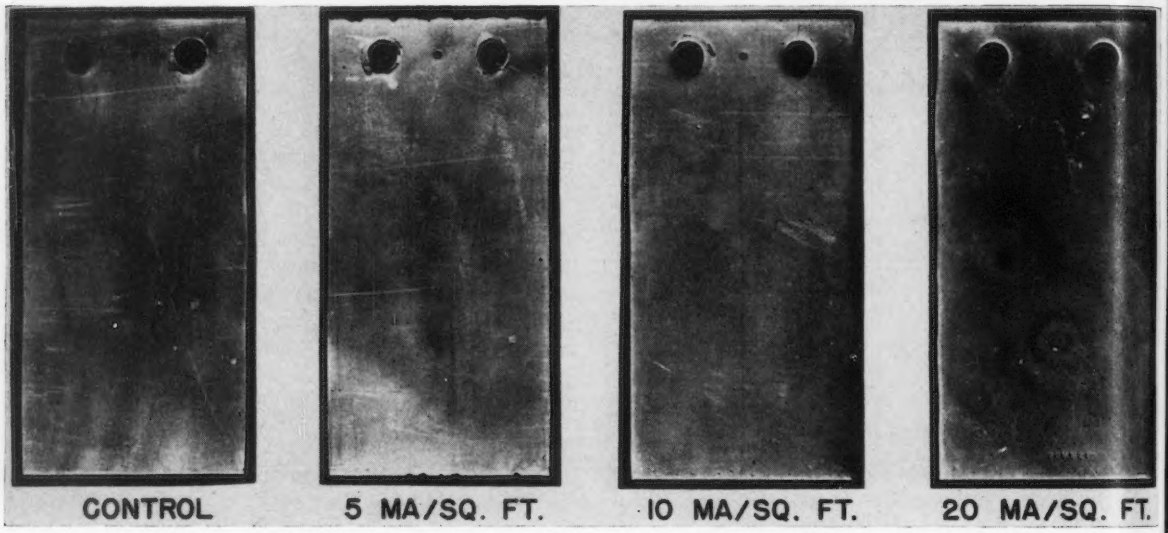

Figure 9—Final condition vs cathodic current density on nickel cathodes after 186 days in quiet sea water.

ma per square foot except for those specimens in the first run which lost their connecting leads for short periods of time.

Monel

The pattern of attack on the unprotected specimen was typical for Monel in sea water. Illustrated in Figure 11, the pits were broad and very shallow with a maximum depth of attack of 0.005-inch in 109 days. No crevice corrosion was observed on any of the specimens. Accordingly the weight losses reflect the reduction of pitting as a result of cathodic protection. Figure 12 reveals that maximum benefit is obtained at 9 to 10 ma per square foot. At this and higher current densities the specimens were virtually unattacked as illustrated by the specimen in Figure 11 after 109 days at 10 ma per square foot. No blistering was observed even at 30 ma per square foot.

Discussion

Pitting on freely exposed surfaces was more frequent and more intense along the edges than on the faces of the stainless steels and nickel. The pitting on Monel was confined to the faces of the specimens. Since Monel is much less susceptible to crevice corrosion produced by oxygen concentration gradients, it would appear that the pitting along edges of the stainless steels and nickel was a form of crevice corrosion in the initial stages. All specimens were exposed in the as-sheared condition and the edges undoubtedly presented numerous micro-crevices which would provide opportunity for the incidence of crevice corrosion and observations of its elimination by cathodic protection.

Beyond consideration of the attack along edges, no attempt has been made here to classify pits or areas of crevice attack in terms of depth of penetration, numbers of areas attacked or area of corroded regions. The reason for this lies in the fact that the incidence of pitting or crevice attack to any degree at all opens the method to suspicion as an effective means of avoiding these forms of attack. Furthermore the erratic or irregular development of sites of crevice corrosion and pitting would render such a treatment useless. On the other hand the optimum current density for a given material probably remains of the same order although the conditions affecting the incidence and intensity of pitting and

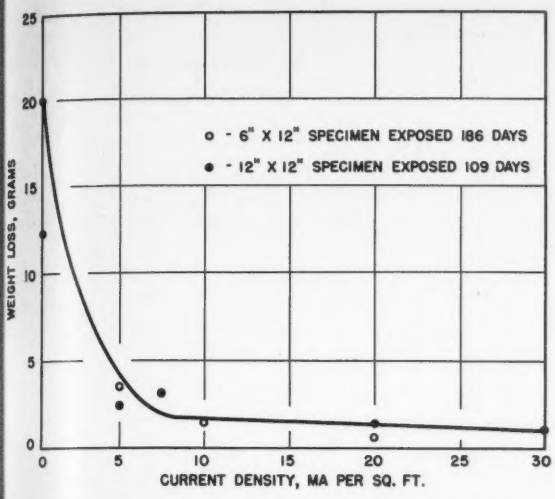

Figure 10—Weight loss vs cathodic current density on nickel cathodes after exposure in quiet sea water.

crevice corrosion may vary from time to time.

With all materials the extent and intensity of local corrosion decreased very sharply with increasing current to about 10 ma per square foot. Further decrease in weight loss was very slight at higher current densities. Monel was almost free of local corrosion at 7.5 ma per square foot and completely free at 10. Very little local corrosion occurred on the other materials at 10 ma per square foot. Complete freedom from local attack was attained at 15 ma per square foot on Type 316 stainless steel and at 20 ma per square foot on Types 302, 410 and 430 and on nickel. Current densities between 10 and 20 ma per square foot were not investigated on all materials and the minimum protective current density was not clearly defined. However, the results would indicate this to be about 15 ma per square foot, a value in the same order as that based upon a comparison of the percent of the area on mild steel and on the passive material that was cathodic in the local cell actions.

As already stated, well defined polarization curves were not obtained. Nevertheless it is evident that freedom from local corrosion is not assured at those current densities below which definite polarization takes place. Considerable reduction of corrosion was noted in this region but complete freedom from local corrosion appears certain only when the metals or alloys are distinctly polarized.

The incidence of blistering on Types 410 and 430 stainless steels at current densities above 10 ma per square foot is of special interest, especially since it was not observed at much higher current densities on the other materials. The photomicrographs in Figure 13 illustrate the nature of the ruptures in three blisters in Type 430 stainless steel. It is noted that the pictured specimen possesses a structure oriented in the direction of rolling and that the blisters appear to prefer the same direction in their development. Examination of a number of blisters did not permit the association of any constituent in the alloys with the incidence of blistering.

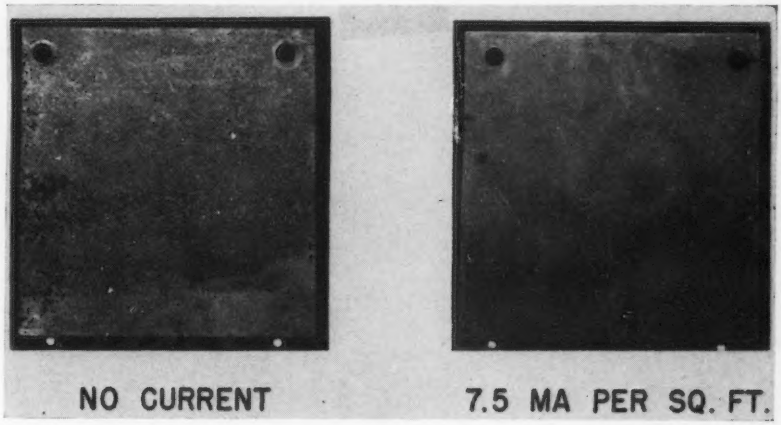

Figure 11—Final condition of Monel with and without cathodic protection after 109 days in quiet sea water.

An analysis of the gas in these blisters showed it to be predominantly hydrogen.

The explanation for the difference in susceptibility to blistering is not immediately clear. However, it does seem that an acceptable one will require that the monatomic hydrogen, which is formed by the current at the cathode surface, diffuse into the lattice structure of the metal where it may combine to form molecular hydrogen. If molecular hydrogen does form within the lattice structure, and cannot diffuse through the alloy in molecular form, blisters will be developed.

Types 410 and 430 stainless steels are ferritic steels with a body centered cubic crystal lattice whereas Types 302 and 316 are austenitic and have a face centered cubic structure. Accordingly one might reasonably suspect that ferrite structures would not permit passage of hydrogen if it could combine to

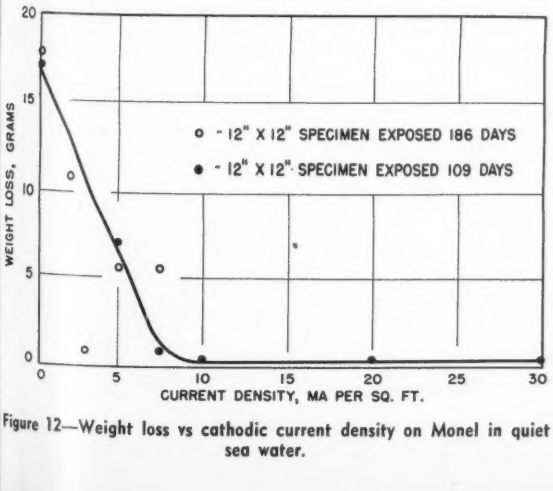

Figure 12—Weight loss vs cathodic current density on Monel in quiet sea water.

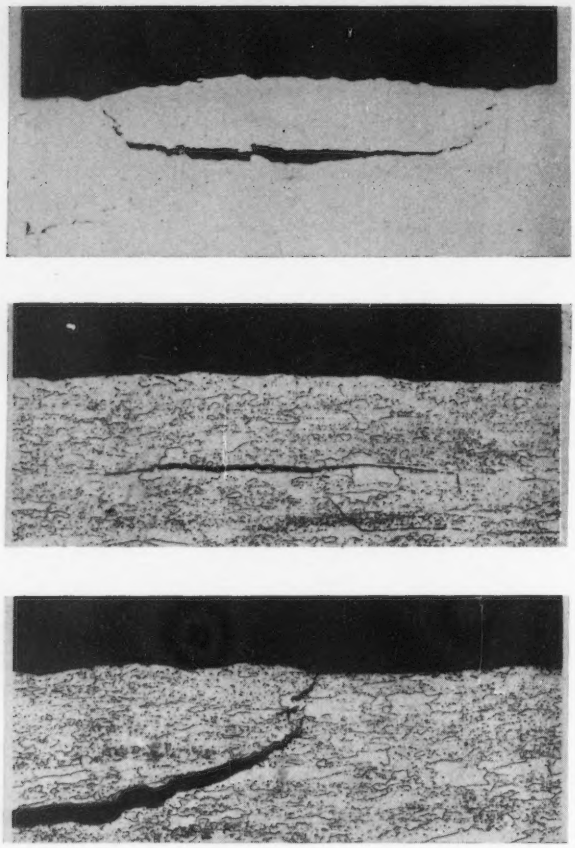

Figure 13—Photomicrographs showing blistered areas in Type 430 stainless steel.

form molecular hydrogen after entering the metal. To test this possibility a high current of 300 ma per sq. ft. was applied to a specimen of low carbon steel which is essentially ferritic in structure. No blistering was observed after several months.

With the elimination of diffusion rates of molecular hydrogen through austenitic and ferritic structures as a probable cause, it would seem that the blistering is associated with the ease with which molecular hydrogen is formed within the alloy or with the rate of diffusion of atomic hydrogen into the crystal lattice of the alloys. These possibilities have not been explored.

The specimens used in these studies were not suitable for investigating possible embrittlement by the hydrogen liberated on their surfaces. As a consequence the embrittling effects of hydrogen from cathodic currents were not included in these studies.

Summary

Cathodic protection has been shown to be useful in preventing crevice corrosion and pitting on nickel and Types 302 and 316 stainless steel when they are immersed in quiet sea water. The pitting of Monel in quiet sea water may also be prevented by cathodic protection.

Types 410 and 430 stainless steels cannot be completely protected by cathodic currents because of the development of hydrogen blisters at current densities below that required for complete protection.

Lack of complete polarization as shown by potential measurements would indicate an uncertain condition in regard to local corrosion on these materials. Complete elimination of crevice corrosion and pitting is indicated by distinct polarization of the materials in quiet sea water.

Acknowledgments

The authors acknowledge the assistance of the Armco Steel Corporation, Eastern Stainless Steel Corporation and the U. S. Steel Corporation for kindly supplying the specimens used in these tests. Acknowledgment is also given C. P. Larrabee of the latter corporation for providing the photomicrographs of blisters in Figure 13 and the analysis of the gas in the blisters.

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A Field Investigation of Cathodic Protection In Glass Lined and Galvanized Water Heaters*

By W. A. DERINGER and F. W. NELSON

Introduction

DURING the course of an investigation of methods for protecting pipe lines from soil corrosion, O. E. Andrus of the A. O. Smith Corporation discovered that cathodic protection of glass-coated pipe lines was much more effective than cathodic protection of bare pipe or pipe coated with organic materials.

When the pipe was coated with a glass coating, Mr. Andrus* found that this coating on buried pipe maintained a high electrical resistance and was substantially unaffected by water. Furthermore, the bond between the glass coating and the steel pipe was such that the hydrogen pressure developed at defective spots in the glass was insufficient to puncture the glass coating or to separate it from the steel base and enlarge the defect. The glass coating was also found to be highly adherent to the steel base, expanded or contracted with the steel base as it changed in dimensions due to changes in temperature. The glass coating alone provided almost complete protection of the pipe from corrosion. Because of the constant high electrical resistance of the glass coating, only a small electric current was needed to supply a long length of pipe line maintained negative with respect to its surroundings, and to cathodically protect from corrosion those portions of the metal which were exposed by the few defects that might occur in any coating. Furthermore, the properties of the glass coating were such that the cathodic protection of metallic areas exposed by defects in the coating was obtained without enlargement of the defects or damage to the coating and a permanently protected pipe line was provided.

The principle of combining cathodic protection with a glass coating to combat corrosion is, of course, applicable to many metallic structures which can be glass coated. The work which resulted in the patent included research in the application of cathodic protection to water heaters and other products and was sufficiently broad to justify, in the claims, the cathodic protection of a glass-fused-to-steel metallic structure by "maintaining the structure electrically negative with respect to its surroundings." In the case of the water heater, the "structure" may be construed to be the inner tank and the "surroundings" to be the hot water in the tank so the research herein reported was really further exploration of one of several specific applications investigated prior to the filing of the application for the above patent.

★A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

*Pat. No. 2,267,361 by O. E. Andrus—U. S. Pat. 12-23-41. Assigned to A. O. Smith Corp.

W. A. DERINGER—Director of Ceramic Research for A. O. Smith Corp., Milwaukee, Wis., which he joined as a ceramic research engineer in 1939. A University of Illinois graduate, with a BS in Ceramic Engineering in 1932, he received his MS from University of Wisconsin in 1943. He is a member of American Ceramic Society, Keramos, Midwest Enamelers Club, Sigma Xi and Tau Beta Pi, Institute of Ceramic Engineers, National Association of Corrosion Engineers, American Water Works Association and a registered engineer in the state of Wisconsin.

F. W. NELSON—Management Ceramic Engineer at the Ceramic Research Laboratory of A. O. Smith Corp., his research in the past four years has been principally in application of cathodic protection of glass-lined structures. A University of Illinois 1939 graduate in ceramic engineering, he was four years with Ingram Richardson Manufacturing Company, three years in the U. S. Navy as electronics engineer and was superintendent of the porcelain enameling division of Greuder, Paeschke and Frey prior to joining A. O. Smith.

Manufacturing Methods

In the past it has been the practice to manufacture glass-lined water heaters on the basis that the glass coating had to be totally continuous. No defects were permitted because the glass coating was the only protection against corrosion of the tank. This fundamental concept of perfect coverage of the glass necessitated many expensive features. First of all the inner tank had to be especially designed to eliminate thermal stresses, sharp edges, weld beads and sharp radii—so as to be assured that the coating would cover the entire interior of the tank. It was necessary to glass coat the parts of the tank (shell, heads and flue) separately so the surface of each part could be carefully inspected. This in turn created a difficult assembly operation because the glass-coated parts had to be welded together in such a way that excessive stresses were prevented. Figure 1a.

Enameling grade iron was required because of the importance of avoiding glass coating defects and defects resulting from a poor steel surface. This necessitated heavier gauges than are ordinarily employed in water heaters—because of the lower physical properties of enameling iron.

Considerable expense and effort went into the inspection of the glass coating. In addition to the visual inspection the parts were checked by exploring the glass surface with a volt-ohmist detector. Many

Abstract

Research started by A. O. Smith Corporation more than twenty years ago demonstrated that the effectiveness of cathodic protection was greatly enhanced when coupled with a glass-fused-to-steel coating. This work resulted in the patent No. 2267361. Subsequent research and field experience with glass-lined domestic water heaters indicated this principle could, perhaps, be applied to advantage in this product. The glass-lining, being an inert, non-conductive coating would impose no current drain on the cathodic protection device used.

Heretofore the glass-lining was the sole protector of water heater tanks against corrosion, and (as in any manufactured product) there was always the possibility the coating might not be perfect. It was thought a magnesium anode might serve as a pinch hitter to protect steel areas exposed if the glass coverage was imperfect.

To evaluate cathodic protection in glass-lined water heaters a rather elaborate field test program was begun, involving installation of four glass-lined and two galvanized water heaters in each of twelve very carefully selected cities in the Eastern half of the United States. Construction of tanks used and the method of installing the magnesium anode is shown. Coatings on all tanks were damaged deliberately to make possible evaluation of the effectiveness of cathodic protection under abnormally adverse conditions. Plans included determination of current flow, anode life, effect of cathodic protection on the coating itself and the possibility of incorporating several cost saving features in glass-lined water heaters when magnesium anodes were used. After installation, these heaters were inspected at regular intervals both visually and electrically. After one year, half the heaters were removed and dissected.

Results of this field test program showed how magnesium anodes behave both in galvanized and glass-lined water heaters under a variety of water and performance conditions. Anode life under these conditions was determined and anode life expectancy graphs are shown. Photographs of many of the bisected water heaters are also shown.

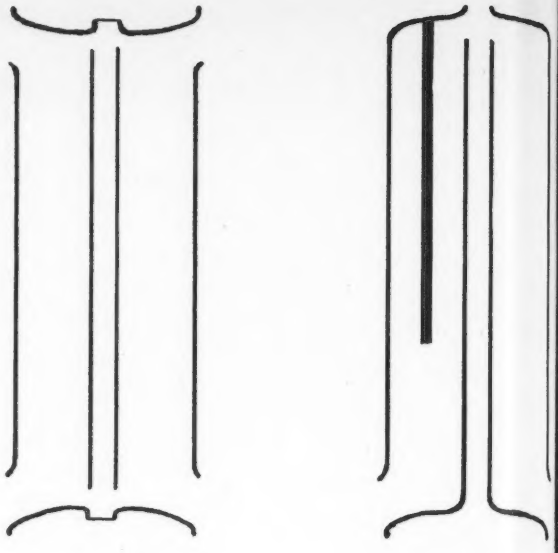
pieces had to be re-coated as a result of this rigorous inspection and the high standards which were required. This resulted in higher manufacturing costs and decreased production.

In spite of these precautions, there was some difficulty in the field because of the task of trying to make every piece perfect on a high volume production basis. If a tiny defect was not seen by the inspector, the galvanic action of the stainless steel spuds and washers, the brass pipe fittings, thermostat and the copper sheath of the electric heating element (in the case of electric water heaters) concentrated on the minute bare metal area of the defect—causing the tank to corrode more rapidly than if there had been no coating in the tank.

The use of cathodic protection with glass-lined surfaces is nothing more than reversing the galvanic action mentioned above. Since 99.99 percent of the steel in a glass-lined tank is covered with an inert, non-conductive coating, the anode is called upon to protect only a few small areas. Consequently, the current drain on the anode is very low while the current density at the exposed metal is high. This assures long anode life and positive protection.

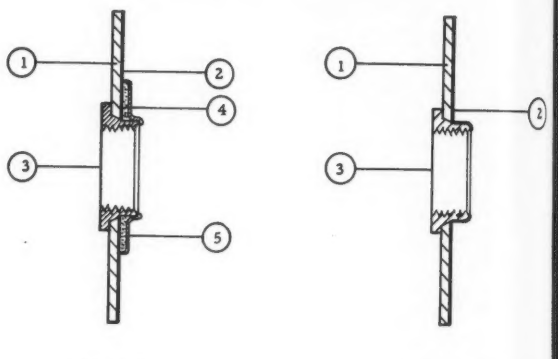
Through the use of cathodic protection, it was thought that numerous cost saving features could be realized as follows:

1. The inner tank could be designed to eliminate 50 percent of the welding after glass coating (Figure 1b).



(a) Old Design (b) New Design

Figure 1—Old and new inner tank design. Simplified two piece construction and elimination of asbestos sealing tape in new design made possible through the use of cathodic protection.



Old Design

1. Tank Wall
2. Glass-Lining
3. 18-8 Stainless Steel Spud
4. Neoprene Gasket
5. 18-8 Stainless Steel Washer

New Design

1. Tank Wall
2. Glass-Lining
3. Carbon Steel Spud

Figure 2—Old and new spud design.

2. The stainless steel spuds and protective washers could be replaced by carbon steel spuds (Figure 2).
3. Minute defects would be allowable and need not be covered by an extra coat of glass.
4. Visual inspection could be used instead of the elaborate electrical inspection procedure.
5. The use of asbestos tape to mask exposed metal in the head-shell and head-flue welded joints could be discontinued.
6. The cost of the base metal could be reduced since it would no longer be necessary to buy premium (enameling grade) steel.

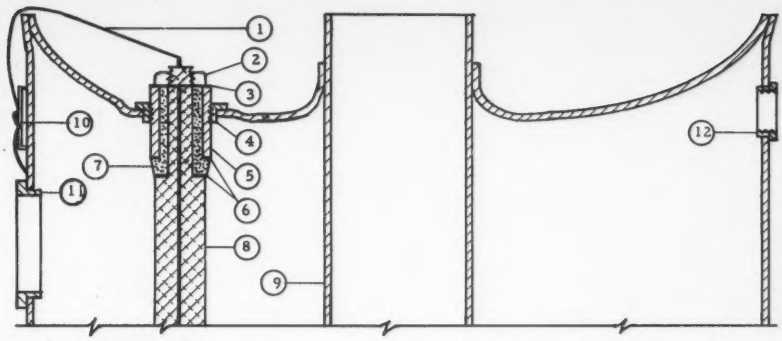
Details of Test Program

A program was inaugurated in 1948 to field test the aforementioned assumptions under actual conditions. At that time magnesium anodes were being adopted and widely publicized by the major manufacturers of galvanized water heaters. It was decided, therefore, to include galvanized heaters with the glass-lined water heaters in this field investigation of cathodic protection.

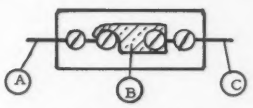
It was planned to place seventy-two test heaters in the field. Forty-eight 30-gallon gas-fired water heaters were glass-lined, incorporating most of the previously mentioned cost saving features. These heaters were made with exaggerated bare metal areas so that the test conditions would be more severe than those encountered by a normal production heater. Twenty-four 30-gallon gas-fired galvanized heaters were coated under normal production conditions so that these heaters would be equal in quality to regular commercial galvanized water heaters.

A preweighed 1.05-inch diameter magnesium anode* was inserted in each galvanized and glass-lined test heater. Rods 24 inches long were placed in half of the heaters and 40-inch rods were placed in the remaining test heaters. The anodes were inserted through a special insulated spud opening in the top head of each heater. (Figure 3.) Connection between the anode and heater shell was made at a four-post terminal board, with the wire from the anode connected to one end post and the wire soldered to the shell connected at the other end post. Each end post was permanently connected to its adjacent middle post. The actual connection between the anode and shell was made with a detachable connecting link between the two middle posts of the terminal board. Thus, instrument leads for voltage and current measurements could be attached at the end posts and the connection could easily be broken by removing the detachable link from the two middle posts. (See Figure 3.)

*Dow Chemical Company extruded high purity magnesium anode containing 3 percent aluminum and 1 percent zinc (FSI) alloy.



1. Connecting Wire
2. 1/2" Hex. Nut
3. Insulating Washer
4. Special 1" Anode Spud
5. Steel Sleeve
6. Neoprene Gaskets and Adhesive Sealer
7. Micarda Insulating Sleeve
8. Magnesium Anode with Steel Core Wire
9. Bare Spot on Flue for Corrosion Check
10. Terminal Board
11. Special 2" Inspection Opening
12. Hot Water Outlets



TERMINAL BOARD WIRING DIAGRAM

A. Anode Wire
B. Jumper
C. Ground wire

Figure 3—Cross section of top portion of field test water heater.

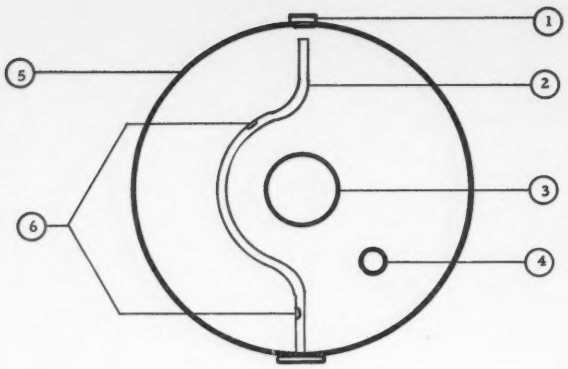
Twelve cities were selected as test sites on the basis of their water analyses (Table I). These cities represented a wide range of water composition: four cities had very soft, low conductivity waters; two had medium soft water; four cities had water of intermediate hardness; and two had very hard water. The heaters were placed in private homes so that normal operating conditions were encountered.

The test heaters were inspected as soon as possible after installation and after 3, 6 and 12 months of service. The field inspection consisted of visual and electrical inspection procedures. The interiors of the tanks were visually inspected through special 2-inch spud openings (Figure 3). A barrel light and dental mirror were used to inspect all portions of the inner tank. Voltage and current readings were taken under both hot and cold water conditions. A special amplifier was built to measure anode and cathode open and closed circuit potentials in relation to a standard calomel cell. The amplifier was a DC push-pull type with a very high impedance. A high impedance was necesary because of the very low permissible current drain on the calomel cell. An electronic switching circuit in the amplifier maintained a normally closed circuit except for the momentary break when

TABLE I

Analyses of Municipal Water Supplies Encountered in Water Heater Field Test Program

CITY	Solids	SiO_2	Fe	Ca	Mg	Na + K	HCO_3	SO_4	Cl	NO_3	Hardness $CaCO_3$	pH	Electrical Conductivity	Source
Boston, Mass.	47	2.0	0.08	4.0	0.9	3.75	8	7	3.8	0.1	15	6.6	70	Surface
Bridgeport, Conn.	54	16.3	0.1	10.4	2.5	4.0	21	11	4.4	0.1	28	7.1	83	Hemlocks Reservoir
Columbus, Ohio	244	5.0	0.0	20.0	7.0	....	47	106	9.0	3.0	74	10.2	398	Scioto River
E. Grand Rapids, Mich.	213	8.5	0.0	110.0	72.0	....	..	55	37.7	..	181	7.6	310	Lake
Kansas City, Kansas	478	12.4	1.7	61.7	20.2	58.0	193	173	16.1	..	239	7.9	757	Missouri River
Kokomo, Ind.	688	17.5	0.25	112.2	27.0	....	..	..	17.0	..	374	7.8	1010	Well
Little Rock, Ark.	28	2.6	0.0	5.0	1.4	4.0	10	4	9.0	..	18	8.5	45	Lake
Milwaukee, Wis.	149	3.5	0.0	34.2	10.9	4.1	127	21	4.7	1.0	130	7.6	260	Lake Michigan
Pittsburgh, Pa.	187	5.9	0.1	26.2	6.1	18.5	8	82	2.6	0.3	99	7.0	246	Allegheny River
Scranton, Pa.	67	3.4	0.2	8.4	2.3	....	..	16	1.9	..	34	6.6	100	No. 7 Reservoir
St. Paul, Minn.	115	2.2	0.0	18.6	9.1	5.0	78	4	4.5	0.1	84	8.5	176	Mississippi R. and Chain of Four Lakes
St. Louis, Mo.	278	10.4	1.4	24.0	13.0	42.0	26	130	20.0	5.8	113	9.1	420	Mississippi River



1. Hot Water Outlet
2. Glass-Lined Corrosion Rod
3. Flue
4. Magnesium Anode
5. Shell
6. Polished Bare Spots

Figure 4—Cross section of top portion of heater showing location of corrosion rod.

readings were taken. This permitted accurate measurements of back emf potentials resulting from polarization of anode and cathode. The calomel cell was inserted into the heater through an adapter and hose assembly attached to the 2-inch inspection opening cover plate. The voltage and current measurements were recorded by a Brush magnetic oscillograph.

Another aid to determining the degree of protection in the various portions of the heater was the use of corrosion specimens in the form of glass-coated steel rods with polished bare metal spots. One of these rods was welded to the cover plate of the 2-inch inspection opening, as shown in Figure 4, and was located in the top portion of the heater and extended around the flue to the hot water outlet. The two polished bare metal spots on this rod were placed so that one was near the anode and the other was near the hot water outlet—180 degrees away from the anode where flue shading was a factor. Another glass coated rod 4 inches in length was inserted near the drain cock. This location was the furthest possible point from the anode since it was 180 degrees away and close to the bottom head. The glass was ground from the end of this rod and the bare metal was polished to a mirror finish.

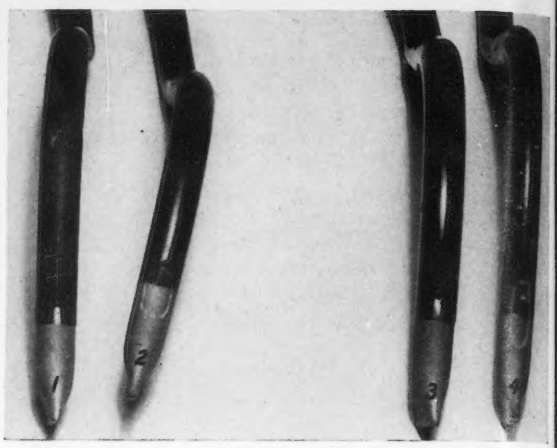


Figure 5—Corrosion specimens removed from water heaters located in Bridgeport, Conn. (1 and 2) and Scranton, Pennsylvania (3 and 4). The bare metal spots on specimens 1 and 3 from glass-lined heaters have their original polished surfaces. Specimens 2 and 4 from galvanized heaters were deeply corroded.

Results of Test Program

Table II gives the average voltage, current and current density measurements for the glass-lined and galvanized test heaters in each city after one year of operation. Little Rock, Arkansas; Boston, Massachusetts; Bridgeport, Connecticut, and Scranton, Pennsylvania had soft, high resistivity water which resulted in low curent densities and ineffective cathodic protection in galvanized tanks. However, the small bare metal areas in the glass-lined tank had much higher current densities and adequate protection was obtained. The current values after one year of operation in cities such as Kansas City, Kansas, and Kokomo, Indiana, were low in galvanized tanks because scale had built up on the interior surfaces and there was not as much of the conductive, galvanized coating exposed.

Pictures of corrosion specimens removed from glass-lined and galvanized heaters after one year of operation in Scranton, Pennsylvania, and Bridgeport, Connecticut, are shown in Figure 5. Half of the polished bare metal spot has been sandblasted to

TABLE II

Voltage, Current and Current Density in Field Test Water Heaters After One Year of Operation

TEST CITY	GALVANIZED HEATERS				GLASS-LINED HEATERS			
	Volts	I (ma)	Total Area Sq. Ft.	Current Density ma/Sq. Ft.	Volts	I (ma)	Total Area Sq. Ft.	Current Density ma/Sq. Ft.
Boston, Mass.	0.67	17.3	18.0	0.96	0.48	1.4	0.021*	67.5
Bridgeport, Conn.	0.64	21.6	18.0	1.20	0.61	1.9	0.021*	91.5
Scranton, Pa.	0.64	17.2	18.0	0.96	0.64	2.2	0.021*	106.6
Little Rock, Ark.	0.65	11.2	18.0	0.62	0.69	1.2	0.021*	57.5
St. Paul, Minn.	0.62	17.0	18.0	0.95	0.64	1.1	0.021*	53.0
Milwaukee, Wis.	0.72	11.5	18.0	0.64	0.90	1.7	0.021*	81.8
E. Grand Rapids, Mich.	0.65	62.5	18.0	3.47	0.85	1.6	0.021*	77.0
St. Louis, Mo.	0.64	45.5	18.0	2.53	0.70	3.5	0.021*	168.0
Columbus, Ohio	0.77	51.1	18.0	2.84	0.70	4.0	0.021*	192.0
Pittsburgh, Pa.	0.76	44.6	18.0	2.48	0.71	9.3	0.021*	447.0
Kansas City, Kan.	0.59	15.7	18.0	0.87	0.88	1.6	0.021*	77.0
Kokomo, Ind.	0.77	30.1	18.0	1.67	0.84	6.2	0.021*	298.0

* Bare metal area in glass-lined heaters estimated to be 3 sq. in. or 0.021 sq. ft.

remove the surrounding glass coating and thereby reveal the depth of corrosion. Note that there was no corrosion on the specimens removed from the glass-lined heaters. These specimens were in the top portion of the heater 180 degrees from the anode—or behind the flue in relation to the anode. Figure 6 is a picture of the corrosion specimens removed from the extreme bottom portion of the Bridgeport and Little Rock heaters. The scale has been removed from one-half of the exposed metal surface. The specimens removed from the glass-lined heater had their original mirror polish. The specimens from the galvanized heaters were corroded.

After one year of field testing, the collected data appeared very favorable so it was decided to recall half of the heaters. One galvanized and two glass-lined heaters were recalled from each city. The heaters were cut along the longitudinal axis and the interior surfaces were closely inspected. The anodes were weighed to determine the loss in weight and the anode life expectancy was calculated. The data are given in Table III and graphically illustrated in Figure 7.

Pictures of the bisected heaters show the left half of each heater as it looked upon removal from the home. The scale was removed from the right half by scrubbing with clear water.

Figure 8 is a galvanized heater recalled from Boston, Massachusetts. Note the deep, rusted corrosion craters which extended halfway through the steel thickness. More corrosion occurred in the area behind the flue due to flue shading effect. Figure 9 is a glass-lined heater from Boston. There were no signs of corrosion in this heater because the current density was high at the small bare metal areas. Figures 10 and 11 are photographs of heaters from Little Rock, Arkansas. The glass-lined heater from Little Rock showed the same freedom from corrosion as was found in the Boston heater while again the galvanized heater was badly rusted.

A galvanized and a glass-lined heater from Pittsburgh, Pennsylvania, are shown in Figures 12 and 13. The water at Pittsburgh is of intermediate hardness and conductivity. There was no corrosion in either heater because the current in the galvanized tank was high and the current density was sufficient for protection. However, the anode in the galvanized heater lost 41 percent of its original weight in one year, while the anode in the glass-lined water heater lost only 7 percent of its weight.

The data obtained in the field test program were conclusive in that there were no discrepancies in the results. All of the information correlated well with corrosion data which had been collected on regular production water heaters.

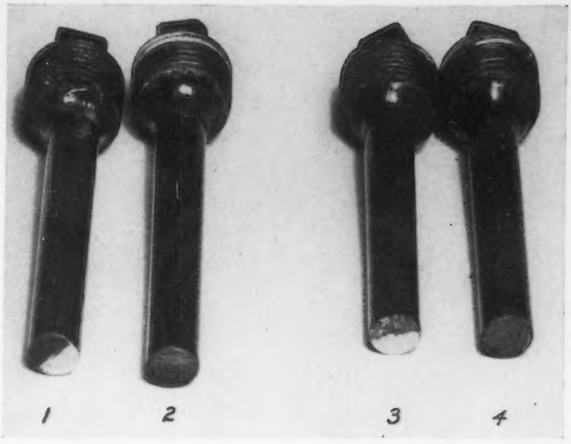


Figure 6—Corrosion specimens removed from the bottom portion of water heaters located in Little Rock, Arkansas (1 and 2) and Bridgeport, Connecticut (3 and 4). Specimens 1 and 3 are from glass-lined heaters and show no corrosion. Specimens 2 and 4 are from galvanized heaters. The scale has been removed from half of the polished bare metal "ends" to show the condition of the underlying metal surface.

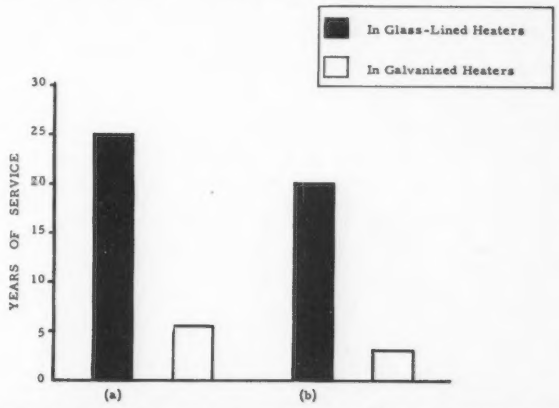


Figure 7—Predicted average anode life in: a. Waters containing less than 120 ppm solids and b. Waters containing more than 120 ppm solids.

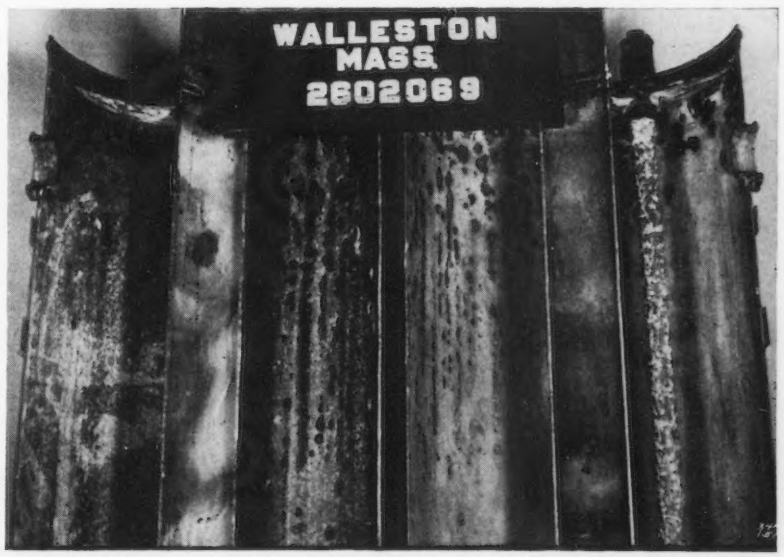


Figure 8—Galvanized field test heater after one year of service in Boston, Massachusetts. The Boston municipal water supply is used in the suburb of Wallaston.

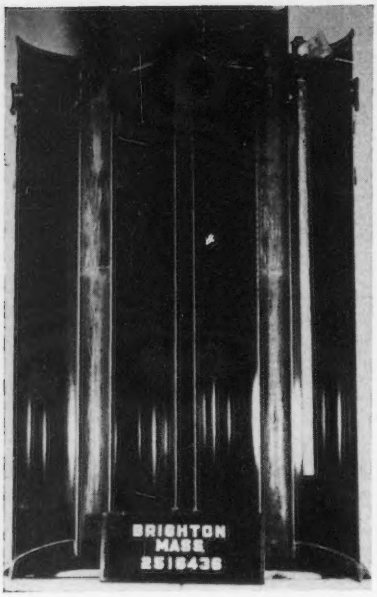


Figure 9—Glass-lined field test heater after one year of service in Boston, Mass. Brighton is a suburb of Boston having the same municipal water supply.

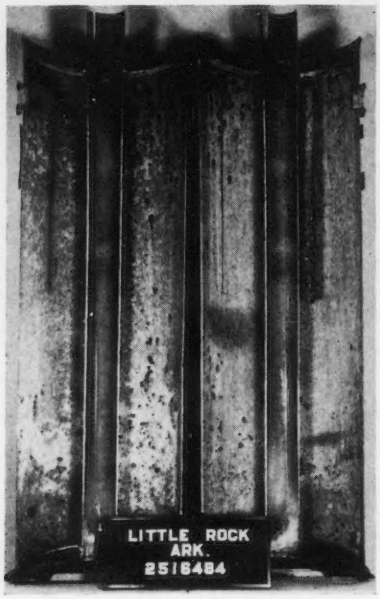


Figure 10—Galvanized field test heater after one year of service in Little Rock, Arkansas.

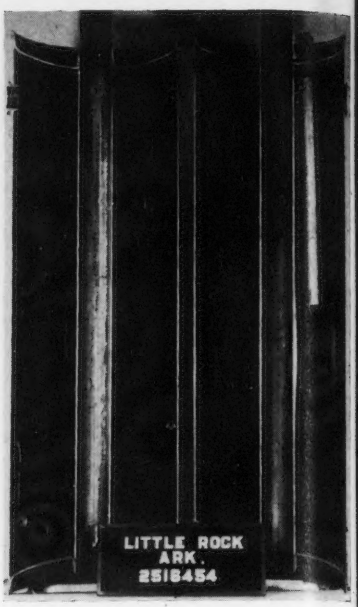


Figure 11—Glass-lined field test heater after one year of service in Little Rock, Arkansas.

The corrosiveness to steel of the various waters encountered in the field test program can be classified as follows:

Boston, Massachusetts ..... Extremely corrosive
Bridgeport, Connecticut ..... Extremely corrosive
Little Rock, Arkansas ..... Extremely corrosive
Scranton, Pennsylvania ..... Extremely corrosive
St. Paul, Minnesota ..... Moderately corrosive
Milwaukee, Wisconsin ..... Moderately corrosive
E. Grand Rapids, Michigan ..... Slightly corrosive—scale forming
Columbus, Ohio ... Slightly corrosive—scale forming
Pittsburgh, Pennsylvania .... Slightly corrosive—scale forming
St. Louis, Missouri . Slightly corrosive—scale forming
Kokomo, Indiana ..... Scale forming
Kansas City, Kansas ..... Scale forming

Conclusions

From the data collected in the first year of the field test program, the following conclusions may be drawn:

1. Magnesium anodes offered complete protection to glass-lined water heaters in all types of waters encountered in this program.
2. Magnesium anodes are not effective in galvanized heaters when the dissolved solid content of the water is below 120 ppm (soft, low conductivity waters).

TABLE III
Magnesium Anode Life Data Based on One Year Tests

TEST CITY	Galvanized Heaters		Glass-Lined Heaters	
	Percent Anode Weight Loss in One Year	Approx. Life Expectancy in Years	Percent Anode Weight Loss in One Year	Approx. Life Expectancy in Years
Boston, Mass.	16.3	6.0*	3.7	27.0
Bridgeport, Conn.	17.2	6.0*	4.7	21.0
Scranton, Pa.	16.5	6.0*	5.8	17.0
Little Rock, Ark.	14.2	7.0*	2.0	50.0
St. Paul, Minn.	20.8	5.0	3.2	31.0
Milwaukee, Wis.	15.5	6.5	3.0	33.0
E. Grand Rapids, Mich.	28.2	3.5	1.5	66.5
St. Louis, Mo.	39.0	2.5	6.8	14.5
Columbus, Ohio	55.2	2.0	4.8	21.0
Pittsburgh, Pa.	40.9	2.5	7.2	14.0
Kansas City, Kan.	32.2	3.0	4.8	21.0
Kokomo, Ind.	25.1	4.0	4.3	23.0

* Anode not effective.

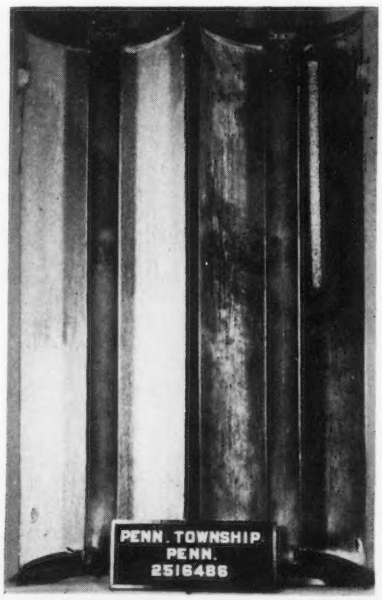


Figure 12—Galvanized field test heater after one year of service in Pittsburgh, Pennsylvania. The Pittsburgh municipal water supply is extended to the suburb of Penn Township.

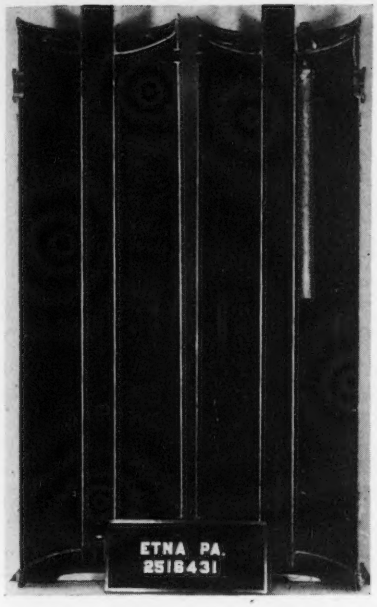


Figure 13—Glass-lined field test heater after one year of service in Pittsburgh, Pa. Etna is a suburb of Pittsburgh, having the same municipal water supply.

3. From the anode weight loss data, it was calculated that a 40-inch magnesium anode of 1.05-inch diameter would have a minimum life of 15 years in a glass-lined water heater.
4. A similar anode in a galvanized heater would have a life expectancy of from two to six years.
5. All of the cost saving features tested in this program are practicable in glass-lined water heater with cathodic protection.
6. A field test program is the most positive method for determining and predicting conditions that will be encountered through normal domestic sales of water heaters.

Acknowledgment

The authors acknowledge the sponsorship of this project by the Water Heater Division of the A. O. Smith Corporation and the guidance and assistance of Mr. O. E. Andrus, manager of the research laboratories. Special mention should also be made of the considerable contribution made to this program by the Electrical Research Laboratory and the Service and Development Laboratory of the A. O. Smith Corporation. We also acknowledge the assistance of A. C. Barzdukas and J. F. Bacher of the Ceramic Research Laboratory in collecting the field data used in this report.

DISCUSSION

Question by Frank Kahn, Philadelphia Electric Co., Philadelphia, Pa.

How were the anodes cleaned of corrosion products for accurate determination of weight loss? Hard adherent accumulations of corrosion products in pits of magnesium anodes are sometimes very difficult to remove manually.

Authors' Reply:

The anodes were scrubbed with a brush and cold water. The remaining corrosion products were removed with dilute chromic acid. Control anodes were used to obtain a correction factor for the slight magnesium loss in the acid treatment.

Question by Kenneth A. Phillips, American Zinc, Lead & Smelting Co., East St. Louis, Ill.:

The city and county areas of St. Louis are served by two different water supply sources. In what part of St. Louis were the test tanks installed?

Authors' Reply:

Galvanized heater—6010 Harney Avenue, St. Louis (North side)

Glass-lined heater—4160 Oleatha Avenue, St. Louis (South side)

Glass-lined heater—724 Tuxedo, Webster Groves (County)

There was no corrosion in either glass-lined heater. The anode weight loss was 6 percent in one year in the glass-lined heater subjected to the St. Louis city water supply and 7 percent in the glass-lined heater tested on the county water supply. The anode in the galvanized heater lost 39 percent of its original weight in one year.

Additional remarks by K. A. Phillips:

In determining whether or not cathodic protection is feasible it is sometimes stated that the content of total solids is an approximate criterion. It is my opinion that the character of these solids, the degree of ionization and certain other factors will so greatly influence the degree of protection attainable that the value of the approximation mentioned above is seriously reduced.

Question by H. A. Robinson, Dow Chemical Company, Midland, Mich.:

Were full length anodes used in the galvanized tanks and, if not, how would you expect that to affect the results?

Authors' Reply:

Both 24-inch and 40-inch anodes were used.

Question by H. A. Humble, Dow Chemical Co., Midland, Mich.:

In your testing program did you find that the magnesium anode had any effct on the glass lining?

Authors' Reply:

None.

Additional Remarks by H. A. Robinson:

The authors are to be congratulated on a development which should go far toward solving the long

standing problem of the corrosion of domestic water heaters.

We note that the galvanized tanks used for comparison were equipped with anode rods of the same (short) length as those used in the glass-lined tanks. While this serves to make the tests comparable as regards rod length, it does place the galvanized tank at some disadvantage since our tests have shown that a full length rod is ordinarily required to completely and uniformly protect a galvanized tank, other conditions being favorable.

We are also inclined to question the conclusion that galvanized tanks cannot be protected with a magnesium anode rod in waters containing less than 120 ppm of dissolved solids. While results will depend somewhat on tank geometry and test conditions, we have observed complete protection of 30-gallon galvanized range boilers operating on treated Lake Huron water containing 60-70 ppm TDS at pH values ranging from 6-10.

Authors' Reply:

Both glass-lined and galvanized heaters were tested in twelve different localities with 24-inch and 40-inch anodes. The 40-inch anodes were found to be no more effective in galvanized tanks in soft water areas than the 24-inch anodes.

In reply to Mr. Robinson's last paragraph, our field test showed a magnesium anode to be wholly ineffective in galvanized tanks in Scranton, Pennsylvania, which has a water of 67 ppm TDS and a pH of 6.6. There was evidence of corrosion in a galvanized heater equipped with a 40-inch anode installed in St. Paul, Minnesota, which has a water of 115 ppm TDS and a pH of 8.5.

Additional Remarks by H. A. Robinson:

With regard to rod length in galvanized vs glass-lined tanks we simply wished to make the point that a full length rod is usually essential to complete protection of galvanized tanks even under favorable water conditions where this may not be true for glass-lined tanks. We recognized that a single, full length anode does not suffice to protect galvanized tanks in the soft, highly aggressive waters. In such instances two or more full length anodes may be needed to establish complete protection. On the other hand, our laboratory work has shown that failure to get complete protection in well mineralized waters can be caused by the use of a short anode which delivers too little current to the bottom portion of the tank. In this respect the glass-lined tank enjoys a distinct advantage in that current distribution is largely controlled by the resistance of the glass coating or liner.

The question of the minimum mineral content at which magnesium anodes cease to be fully effective in galvanized tanks is likely to remain controversial because so many other factors affect the result. The nature of the dissolved solids, pH, temperature, rate of through-put of water, dissolved O_2 content and tank proportions are some of the more important variables. In view of this it is unreasonable to expect that total solids content alone can ever become a wholly reliable index or, if used, can be expressed only as a range. The important and significant observation would appear to be that the protection afforded in glass-lined tanks is practically unaffected by the water composition and operating variables which alter the results in galvanized tanks.

Question by R. P. Devoluy, Woolsey Paint & Color Co., New York City:

What was the temperature of the water in the heater tanks?

Authors' Reply:

Between 140 and 160 degrees.

The Chemical Resistance of Phenolic and Furfuryl Alcohol Type Coatings*

By RAYMOND B. SEYMOUR and ROBERT H. STEINER

AS A RESULT of recent improvements in baked coatings based on modified phenolic resins and the introduction of acid-setting room temperature curing coatings based on phenols and polyfurfuryl alcohol as replacements or alternates for the standard baked phenolic coatings, a large number of infusible chemical resistant coatings are now available. Unfortunately, most manufacturers' literature is vague on the actual physical and chemical properties of these products and little comparative chemical resistant data are available. Therefore, as a service to corrosion engineers, data on the resistance of these resinous coatings to typical acids, alkalies and solvents, as well as data on the flexibility and temperature shock resistance are presented in this paper.

These comparative data could have been secured using laboratory prepared resins and specific formulation data could be published. However, from a practical point of view, such data would be criticized as being somewhat academic and, therefore, commercially available proprietary coatings were used even though it is impossible to publish precise formulation data for such products. Since these materials are described generically, comparative data with other proprietary coatings can be obtained readily.

For the sake of brevity, the coatings will be designated as follows:

A—A commercially available phenolic coating containing liquid resin and about 15 percent volatile solvent. This product is compounded at the time of use by adding about one part by weight of a solution containing an acid setting agent to seven parts by weight of a liquid resin. This product hardens overnight at room temperature but because it is dependent upon an acid-type catalyst, cannot be used directly on concrete or steel but must be preceded by a suitable primer system. Coatings of this type have been widely publicized in many non-technical magazines and are recommended by various manufacturers as chemical resistant coatings.

B—A commercially available coating related to A in that it is based on a phenolic solution. It contains approximately 70 percent volatile solvent and is cured by heating for 10-20 minutes at a temperature of 375-400 degrees F. Products of this type have been widely used as tank coatings and as a general chemical resistant lining for mild service, such as for food and solvent storage.

C—A commercially available substituted phenolic coating applied from a solution containing about 70 percent volatile solvent. This product is baked for approximately 20 minutes at 375-425 degrees F after application. Preliminary data indicate that Type C will replace Type B to a large extent since it has greater resistance to alkalies, superior adhesion and flexibility and may be secured in a wide variety of colors.

D—This commercially available product is compounded at the time of use by adding about one part of an acid-containing solution to seven parts of the resin solution which contains about 10 percent volatile solvent. As in the case of A, this product must be used over a primer system. This product is available only as a jet black coating and unlike previously available coatings based on furfuryl alcohol, has considerable flexibility.

Legend: A—Koraloy 470; B—Korezite; C—Duvon; D—Alkaloy 550.

★A paper presented at the Seventh Annual Conference and Exhibition, National Association of Corrosion Engineers, New York, N. Y., March 13-16, 1951.

RAYMOND B. SEYMOUR—Executive Vice-President and Technical Director of Atlas Mineral Products Co., Mertztown, Pa., holds degrees from the University of New Hampshire and a doctorate of philosophy at University of Iowa, 1937. He has been Research Chemist for Goodyear Tire & Rubber Co., Director, Industrial Research Institute, University of Chattanooga, Tenn., and has held various positions with Atlas Mineral Products Co. He is author and co-author of several papers on paints, finishes and industrial research.

ROBERT H. STEINER—Research Director of Atlas Mineral Products Company, Mertztown, Pa., he holds a BS Chem degree and Ph D from the University of Pittsburgh. He was research chemist for Firestone Tire and Rubber Company for seven years specializing in vinyl resins and plastics before joining Atlas in 1950.

Spot Tests

Considerable data can be secured on the chemical resistance of coatings by the use of spot testing techniques. In this phase of the investigation, drops of various solutions were applied to 10 mil sprayed coatings on properly prepared sandblasted steel and the results were observed after standing 36 hours uncovered at room temperature. Four or five spray coats were usually required to secure a 10 mil thickness.

As shown by the data in Table I, all four coatings

TABLE I

Comparative Resistance of Coatings to Non-Oxidizing Inorganic Acids

Test Solution	A	B	C	D
85 Percent Phosphoric Acid	E	E	E	E
10 Percent Hydrochloric Acid	E	E	E	E
35 Percent Hydrochloric Acid	E	E	E	E
10 Percent Sulfuric Acid	E	E	E	E
50 Percent Sulfuric Acid	1	E	E	E

Legend:

E—not attacked
1—slightly red
2—red
3—slightly dull
4—dull
5—slightly etched
6—etched
7—cracked
A—completely attacked

Abstract

Spot tests on panels, quantitative resistance tests on unsupported films and long term tests on immersed coated plummets were run in order to determine the corrosion and solvent resistance of acid-catalyzed phenolic coatings, baked phenolic coatings, baked modified phenolic coatings, and acid-catalyzed polyfurfuryl alcohol coatings. In general, all coatings tested had excellent resistance to solvents, non-oxidizing acids and salts over a wide range of temperature. The phenolic coatings had superior resistance to oxidizing acids and the baked modified phenolic coatings were superior to the baked and acid-catalyzed phenolic coatings. However, all phenolic coatings were attacked by high concentrations of oxidizing acids and by more dilute solutions at elevated temperatures. All tests on acid-catalyzed polyfurfuryl alcohol coatings showed these coatings to be completely resistant to alkalies in all concentrations over a wide range of temperature. Tests on coated plummets indicated that practical tests gave good correlation with both qualitative and quantitative screening tests on panels and unsupported films.

were resistant to typical non-oxidizing inorganic acids.

As shown in Table II, none was satisfactory for even dilute nitric acid but B exhibited the best resistance to dilute chromic and concentrated sulfuric acid. C was apparently superior for sodium hypochlorite service.

TABLE II

Comparative Resistance of Coatings to Various Solutions of Oxidizing Agents

Test Solution	A	B	C	D
96 Percent Sulfuric Acid	2	E	6	7
10 Percent Nitric Acid	A	5	6	5
25 Percent Nitric Acid	A	5	A	6
50 Percent Nitric Acid	A	6	A	6
5 Percent Chromic Acid	3	E	3	3
10 Percent Chromic Acid	4	E	4	4
5 Percent Sodium Hypochlorite	3	3	E	4

Legend:

E—no attack
1—slightly red
2—red
3—slightly dull
4—dull
5—slightly etched
6—etched
7—cracked
A—completely attacked

As shown in Table III, coatings A and B were not resistant to dilute solutions of sodium hydroxide but were apparently satisfactory for alkaline conditions having lower pH's such as sodium bicarbonate, sodium carbonate and trisodium phosphate. Coatings C and D were resistant to all alkalies tested.

TABLE III

Comparative Resistance of Coatings to Aqueous Alkaline Solutions

Test Solution	A	B	C	D
1 Percent Sodium Hydroxide	1	2	E	E
5 Percent Sodium Hydroxide	2	5	E	E
10 Percent Sodium Hydroxide	6	6	E	E
10 Percent Sodium Bicarbonate	E	E	E	E
10 Percent Sodium Carbonate	E	1	E	E
10 Percent Trisodium Phosphate	E	1	E	E

Legend:

E—not attacked
1—slightly red
2—red
3—slightly dull
4—dull
5—slightly etched
6—etched
7—cracked
A—completely attacked

As shown in Table IV, none of the coatings was affected by corn or motor oil, oleic acid or by aqueous solutions of citric, acetic or formic acid under the conditions of test.

TABLE IV

Comparative Resistance of Coatings to Oils and Organic Acids

Test Solution	A	B	C	D
Corn Oil	E	E	E	E
Motor Oil	E	E	E	E
Oleic Acid	E	E	E	E
25 Percent Citric Acid	E	E	E	E
50 Percent Acetic Acid	E	E	E	E
50 Percent Formic Acid	E	E	E	E

Legend:

E—not affected

As shown in Table V, none of these coatings was affected by aqueous solutions of ammonia or tetraethylene pentamine. However, coatings A and B became red in the presence of 10 percent sodium silicate, C became slightly dull when immersed in pyridine and both C and D were affected by aniline.

TABLE V

Comparative Resistance of Coatings to Miscellaneous Alkaline Solutions

Test Solution	A	B	C	D
10 Percent Aqueous Ammonia	E	E	E	E
—Aqueous Ammonia	E	E	E	E
10 Percent Sodium Silicate	2	2	E	E
Pyridine	E	E	3	E
Tetraethylene Pentamine	E	E	E	E
Aniline	E	E	1	3

Legend:

E—not affected
1—slightly red
2—red
3—slightly dull

Resistance of Coated Panels to Various Solvents

In order to amplify the solvent resistance of these coatings, ½ x 1½ inch tinplate panels coated with 10 mil coatings were immersed to one-half their depth in typical solvents at 77, 160 and 250 degrees F in accordance with ASTM Method D-870-46T. Because coating A would not withstand temperatures of 250 degrees F, no tests were made with coating A at this elevated temperature. The top temperature of the other coatings was limited only by the boiling point of the selected solvent.

TABLE VI

Comparative Resistance of Proprietary Coatings to Solvents at Elevated Temperatures

	A		B			C			D		
Test Solution, °F.	77	160	77	160	250	77	160	250	77	160	250
Alcohols	E	E	E	E	..	E	E	..	E	E	..
Ketones	E	E	E	E	E	A	A	A	E	E	E
Ethers	E	..	E	..	..	..	E	..	E	..	..
Esters	E	E	E	E	..	A	A	..	E	E	..
Aliphatic	E	E	E	E	E	E	E	E	E	E	E
Hydrocarbons Aromatic	E	E	E	E	E	E	E	E	E	E	E
Chlorinated Aliphatic Hydrocarbons	E	E	E	E	..	E	E	..	E	E	..
Carbon Disulfide	E	..	E	..	..	E	..	..	E	..	..
Furfural	A	A	A	A	A	A	A	A	E	E	A
Pyridine	A	A	A	A	..	A	A	..	E	E	..

Legend:

A—attacked
E—unattacked

Note: All tests were run at temperatures below the boiling point of the selected solvents.

Quantitative Chemical Resistant Tests on Free Films

Films 6 to 10 mils in thickness were built up on 3 x 1½ inch tin panels and the resulting films after being cured were removed by peeling. Films of coating C were obtained in the same way except that it was necessary to use concentrated hydrochloric acid to attack the metal in order to free the film. Unfortunately, free films of coating B could not be obtained by this method due to the inherent brittleness of the baked unmodified phenolic coating. Dried films were weighed and then immersed in the test solutions at various temperatures for 7, 14, 21 and 60 days. The weight changes were calculated as mg/sq. in. of total surface. As shown in Table VII, films of coating A were not affected any more in concentrated hydrochloric acid or 25 percent sulfuric acid than in distilled water. However, these films were progressively attacked with time when immersed in sodium hypochlorite solutions.

TABLE VII

Change in Weight With Time of Immersed Films of Coating A

Test Solution	Temp. (°F.)	LOSS IN WEIGHT (Mg/In²) 7 Days	14 Days	21 Days	60 Days
Water	77	6.5	6.3	5.6	7.6
	140	10.7	9.0	8.9	9.3
	195	11.0	10.6	8.4	9.2
35 Percent Hydrochloric Acid.	77	4.2	1.3	3.8	4.7
25 Percent Sulfuric Acid	77	1.9	1.3	1.7	1.8
	140	4.8	5.2	5.4	5.6
	195	11.2	10.9	10.3	11.1
5 Percent Sodium Hypochlorite	77	11.1	27.6	45.0	....

As shown in Table VIII, films of coating C gained weight in all solutions and the gain in 50 percent sulfuric acid was essentially the same as that in distilled water. The gains in weight in concentrated hydrochloric acid and glacial acetic acid are somewhat higher than in water and these gains appear to progress with time. However, it is questionable whether or not any significance can be placed on these specific data. Likewise, there is a similar gain noted for free films immersed in 10 percent sodium hydroxide but there is no evidence of chemical attack. The solutions for immersion in all cases were chosen to supply as much significant data as possible.

TABLE VIII

Change in Weight With Time of Immersed Free Films of Coating C

Test Solution	Temp. (°F.)	GAIN IN WEIGHT (Mg/In²) 7 Days	14 Days	21 Days	60 Days
Water	77	0.3	0.4	0.6	0.6
	140	0.5	0.4	0.6	0.7
	195	0.4	0.4	0.5	0.6
35 Percent Hydrochloric	77	2.3	3.6	3.8	3.4
50 Percent Sulfuric Acid	77	0.3	0.3	0.3	0.4
	140	0.3	0.1	0.5	0.4
	195	0.3	0.2	0.3	0.4
Glacial Acetic Acid	77	*4.2	5.3	6.5	6.7
10 Percent Sodium Hydroxide	77	0.3	0.5	0.6	0.7
	140	0.5	2.1	1.7	2.3
	195	3.0	3.6	4.0	4.3

As shown in Table IX, free films of coating D gained weight in most solutions but lost weight in 10 percent sodium hydroxide at 195 degrees F. This loss was not great and did not progress exceedingly with time. These data coupled with practical experience indicate that coating D is satisfactory for use in aqueous sodium hydroxide. However, the loss was rapid in 5 percent chromic acid at room temperature and progressed significantly with time.

TABLE IX

Change in Weight With Time of Immersed Free Films of Coating D

Test Solution	Temp. (°F.)	CHANGE IN WEIGHT (Mg/In²) 7 Days	14 Days	21 Days	60 Days
Water	77	+ 0.8	+ 1.9	+ 2.8	+ 2.6
	140	— 0.4	+ 0.1	+ 0.7	— 0.2
	195	+ 1.0	+ 7.4	+10.5	+ 8.3
50 Percent Sulfuric Acid	77	+ 0.3	+ 0.3	+ 0.2	+ 0.5
	140	+ 0.2	+ 0.3	+ 0.2	+ 0.4
	195	+ 1.5	+ 5.8	+ 3.4	+ 4.3
5 Percent Chomic Acid	77	—43.5	—80.0	—90.0	....
10 Percent Sodium Hydroxide.	77	+ 0.4	+ 0.9	+ 1.5	+ 1.0
	140	+ 0.1	+ 0.8	+ 0.7	+ 0.9
	195	— 2.3	—3.1	— 3.8	— 4.3

Immersion Tests of Coated Plummets

Small test plummets were constructed by rounding off the corners and drilling a small hole in one end of a 2-inch cylinder having a diameter of ½-inch and cementing a loop of Teflon in this hole through the use of a proprietary corrosion resistant cement* known for its adhesion to metal surfaces. This test plummet was then dip-coated until a 5 mil thick pinhole-free film was built up. All coated plummets were tested with an electric spark tester using low voltage in order to ascertain that films were pinhole-free before being tested. All tests were conducted for 60 days in various solutions at 160 degrees F.

As shown in Table X, none of these test samples was affected by 50 percent sulfuric acid or 50 percent acetic acid. Coating B was resistant to 10 percent chromic acid at 77 degrees F but was not satisfactory for higher temperatures. A and B were badly attacked by 10 and 20 percent solutions of sodium hydroxide but plummets coated with C and D were unaffected by sodium hydroxide in either concentration.

TABLE X

Effect of Various Solutions on Coated Plummets at 160° F

Test Solution	A	B	C	D
25 Percent Sulfuric Acid	E	E	E	E
50 Percent Sulfuric Acid	E	E	E	E
50 Percent Acetic Acid	E	E	E	E
10 Percent Chromic Acid (77° F.)	A	E	A	A
10 Percent Sodium Hydroxide	A	A	E	E
20 Percent Sodium Hydroxide	A	A	E	E

Legend:
A—attacked E—unattacked

Impact Resistance and Flexibility

Steel panels 30 mils thick were coated with 2-mil coatings and these coated panels were subjected to the Gardner Reverse Impact Test. While coatings A, B and D failed at 2 inch pounds, coating C was satisfactory at the limit of the instrument, viz., 28 inch pounds.

When 5-mil thick films on 30-mil thick steel panels were bent through a 180 degree angle around mandrels decreasing in size from 1-inch to ⅛-inch, sam-

* Alfane.

ples A, B, and D failed on the 1-inch mandrel, whereas coating C passed the ⅛-inch mandrel test.

Effect of Temperature on Coated Samples

In order to determine the effect of temperature, sandblasted steel panels with 10 mil thick coatings were heated for one hour at 120 degrees F in an air oven and then the temperature was increased in approximately 15 degree F steps until failure. Under this test, film A cracked at 150 degrees F, film D cracked at 220 degrees F, film B discolored at 280 degrees F but did not crack, while C was unaffected in any noticeable way at 360 degrees F. It should be pointed out that the high temperature resistance of D is typical only for modified furfuryl alcohol coatings since most proprietary furfuryl alcohol coatings will crack at 150 degrees F or below.

As a further test of the effect of temperature, these coated panels were heated for one hour at 120 degrees F and then plunged into ice water. The oven was then raised to higher temperatures in 15 degree F steps and the tests were continued until the sample cracked. Under this test, film A cracked at 150 degrees F, film D cracked at 220 degrees F, but films B and C were still uncracked at a temperature of 400 degrees F at which the test was discontinued.

Conclusions

Based on the test data presented, it may be concluded that any one of the coatings described in this paper is resistant at room temperature to aqueous solutions of non-oxidizing inorganic acids, alkalies having a pH of less than 10 and most non-alkaline solvents with the exception that a baked modified phenolic coating was softened by ketones and esters and all phenolic coatings tested were attacked by furfural. The furfuryl alcohol polymer and the baked modified phenolic coating are apparently resistant to alkaline solutions having a pH greater than 10 even at elevated temperatures. Providing the coating is resistant to the solution under consideration, a baked coating is preferred and the baked substituted phenolic coating is apparently superior because of its excellent resistance to heat and mechanical shock.

Acknowledgment

The efforts of Messrs. Carl DeLong and Gerald Gilbert, Jr., who cooperated in supplying data for this paper, are gratefully acknowledged.

DISCUSSION

Question by Albert K. Ackoff, Rochester, N. Y.:

What is type and manufacturer of the voltage tester used in the tests for film continuity and what voltage is used?

Authors' Reply:

The voltage tester that has been used by us for some time both in laboratory and field work is manufactured by Master Appliances, Inc., 1600 Factory Ave., Marion, Ind. This is a convenient and low-priced tester. We do not measure the voltage but adjust the Variac so that a spark passes across the gap when the tester is held approximately ⅛-inch from the uncoated metal surface. We ascertain that we use a minimum voltage since the higher voltages will actually cause a coating to be broken down.

Question by S. A. Lewis, U. S. Stoneware, New York, N. Y.:

Virtually all commercial furfuryl alcohol coatings developed thus far for use on metals are so inherently brittle as to preclude their general use. Was the coating under discussion a standard one developed for normal use or was it something special made up for these tests?

Authors' Reply:

The flexible furfuryl alcohol base coating is a commercial product and is described in a reference in the paper in accordance with its trade name. Patents have been applied for and we would not be permitted to divulge further information on composition until the patents are issued. We, of course, admit that previously available furfuryl alcohol coatings have been very brittle and were pleased to report this phase of our research laboratory progress.

Part II of Two Parts

Some Aspects of Ship Bottom Corrosion*

By PAUL FFIELD*

(This is Part II of an Article the first portion of which was published in Corrosion, Vol. 8, No. 1, 29-48 (1952) Jan.)

DISCUSSION

Mr. David Arnott, Vice-President: All my experience would go to show the relative superiority of the iron over the steel ship to resist corrosion under service conditions. In my early days it was not uncommon for owners to specify wrought iron for an unsheathed weather deck and even to require an iron shell for vessels whose service location did not permit of regular drydocking. I do know that drilling of the shell plating of these old iron ships shows very little reduction from their original scantlings. It is, therefore, somewhat surprising that according to Table I sandblasted wrought iron shows the highest rate of corrosion and depth of pitting. Like most of our ship troubles, excessive or unusual corrosion is generally the result of a combination of circumstances rather than some single specific cause. Stray currents from welding operations during outfitting has come into the picture as a primary factor in the serious pitting of shell plates even prior to the vessel's delivery and this aspect of the question is dealt with very completely in the paper. All the evidence would go to show that the complete removal of mill scale by pickling or sandblasting would be beneficial. On the other hand, the author's statement, that freedom from mill scale trouble can be obtained if the weathering is adequate, the paint is suited for application over mill scale, and the vessel is drydocked at three to six months' intervals during the first year, is fully borne out by experience where a good quality paint is used after adequate cleaning and the paint is applied under suitable weather conditions. Figures 23 and 24 showing the effect of a wash coat primer in eliminating blistering trouble are new to me and the warning given in the last paragraph of the Appendix would appear to be of sound practical value.

Corrosion trouble on ships seems to occur in cycles. When Mr. Bennett presented his paper in 1926[22] our particular trouble was with the rivets rather than with the plates. The use of puddled wrought iron rivets strongly advocated in the paper had a vogue for a limited period with certain tanker owners but was later discontinued as the wholesale replacement of badly corroded and underflush steel rivets with iron rivets did not provide a complete answer to the problem. As a matter of fact the type of rivet point driven in those war-built ships was, in my opinion, largely responsible in that they were either overcalked as a matter of routine or the rivet material overlapped the edge of the countersink in the form of a thin fin which was conducive to corrosion attack.

The author's use of the word "heterogeneous" in connection with ship steel is unusual but correct, as commercial steel can be said to be homogeneous only in spots. Rivets manufactured from rimmed steel rods are decidedly heterogeneous. A sulphur print of a section of a rimmed steel rivet shows a characteristic outer ring free from inclusions surrounding a comparatively soft inner core with marked sulfur segregations. I have long been of the opinion that a lot of our corroded rivet troubles in our seagoing ships may be due to the use of rimmed steel rivets and I would like to ask Mr. Ffield if he has made any investigation along these lines?

The author is to be congratulated on the very thorough and practical maner in which he has tackled a difficult and highly controversial subject.

Mr. B. E. Meurk, Member: This is an excellent paper and we are fortunate in having such a contribution to our *Transactions* for future reference. The author has explored galvanic corrosion due to the presence of mill scale so thoroughly that there is no cause for comment. I agree with everything that has been said.

I note, however, on page 34 that the author states, "While it is not always possible, there are occasions when conditions may be improved by leaving the paint off the material which is corroding and painting the material which is not corroding." This statement is so contrary to usual ship bottom painting procedures that I should appreciate having Mr. Ffield elaborate on the occasions on which he has found it beneficial to coat the cathode and not to coat the anode in a galvanic circuit. On page 36 in the third paragraph recommending ways of avoiding mill scale corrosion, the statement is made that "Painting must be relied on to prevent exposure of bare steel to water or preventing water from reaching the mill scale." I will agree with this statement if the word "or" is changed to "and" as it will then conform with our regular practice in preserving the underwater body of a ship.

It is correct and logical to establish a procedure to drydock ships with mill scale at close intervals so that all loose scale can be removed immediately, if possible, and the hull properly covered with paint. It is also necessary to remove immediately ferrous scale that accumulates on a ship's bottom as this scale has

★Presented at the annual meeting of The Society of Naval Architects and Marine Engineers in New York on November 10, 1950. Reprinted from *Trans. Soc. Naval Architects and Marine Engrs.*, **58**, 608-657 (1950).

* Superintendent of Development and Research, Bethlehem Steel Company, Shipbuilding Division, Quincy, Mass.

the same effect as far as corrosion is concerned as mill scale. If rusting takes place underneath paint, we always find a hard flint-like scale consisting of black magnetic oxide and ferrous oxide, which when entrained oxygen in the water is blanked off cannot revert to the ferric form. For new construction, or after sandblasting of the plates of a vessel in service if time will allow, ordinary red lead with linseed oil is a very good prime coat but this must be allowed to oxidize completely or dry before anti-corrosive and anti-fouling paints are applied. It generally requires about six hot summer days to accomplish this drying process and it is therefore impractical to use the linseed oil red lead in the course of ship repairs during drydocking periods. Instead we have in the past used the fast-drying red leads fortified with chromate or other primers with chemical inhibitors. We have also experimented during the past year with a washcoat primer. This has been tried on only one of our vessels and appears to have held up very well on examination at the first drydocking after application. Although our experience with this type of primer is very limited, we sincerely hope that we can also conclude that these primers constitute one of the significant advances in marine paint technology.

In addition to pitting corrosion due to velocity, stray currents and galvanic currents all of which have been thoroughly covered by the author, we have also experienced another type of corrosion caused by marine growth. As an illustration of this, I would like to call attention to our experience on the Great Lakes where the Isthmian Steamship Company, as well as other subsidiaries of our parent company, operated a large fleet year in and year out for some thirty odd years with bare steel bottoms. Formerly, fresh water of the Great Lakes was considered to be such that no corrosion could occur. However, during the depression years of 1931, 1932, and 1933, when 75 percent of our lake tonnage was tied up, we suddenly discovered that the hulls on all these vessels were attacked in a most vicious maner by pit corrosion. Those vessels, moored in the purest and finest lake water, were attacked to a greater degree while vessels that had been placed in foul water, that is, water containing sewage from cities or chemical plants, in some cases showed no corrosion at all.

A Corrosion Committee was formed, composed of some of the most experienced scientists and talented experts in the corrosion field to deal with this problem. Many far-reaching ideas were proposed but no definite conclusions were reached as to the cause. I remember that someone even suggested that iron bacteria changed soluble ferrous carbonate into insoluble ferric hydroxide which was the beginning of a ferric oxide formation. It was my belief, however, that the cause of the corrosion was due to the fact that while the vessels were lying still, the spores of fresh water algae attached themselves to the hull consuming carbon dioxide, expelling oxygen and forming oxygen concentration cells which started the pit corrosion. I observed some ships on drydock and you could notice a fringe-like formation when the ship was wet, but immediately when it became dry it disintegrated in the air into some kind of dark powder. The entire steel surface of the hulls was peppered with carbuncular protrusions each one having a pit underneath. Some of these carbuncles protruded up to almost ⅜ inch with a pit underneath in the plate of about the same depth. The construction of these protrusions was very interesting; the upper part above the surface of the plate was principally ferric oxide with a gray-brown core, then at the surface of the plate was a continuation of the plate surface appearing almost like a thin black mill scale which, of course, it was not, and underneath was the pit filled with a jet black liquid. This black liquid was nothing but finely diffused ferrous oxide and water.

After several meetings, the Corrosion Committee, although not in agreement as to the cause, agreed on the policy of drydocking all vessels and having them thoroughly sandblasted and coated with a lead chromate primer followed by an anti-fouling coating containing cupric oxide and this solved our problem. It was not necessary, of course, to introduce arsenic or mercury as toxics since in fresh water there is no barnacle growth.

I agree with the author that cathodic protection by means of zinc or steel slabs is not of great value. I have never tried the magnesium slabs but believe they may have some merit. In my opinion, corrosion pads of soft steel are better than zinc since when these pads corrode ferric hydrate is continuously formed and washed away thereby giving some protection against rusting while at the same time keeping the surface of the corrosion pad clean and active at all times.

About 1923 or 1924, we removed all zinc plates from the sterns of our vessels and we have never found any difference as far as corrosion is concerned. We do paint our propellers with regular bottom paint in order to insulate the surfaces but after about nine months we generally find that the entire propeller blades are almost devoid of paint. No doubt, such painting gives some insulating effect, but if a proper coating could be obtained that would adhere better to the propeller with a bright surface and still be flexible to withstand the deflection of the propeller blades without cracking, I believe it would be most effective in preventing galvanic corrosion of the hull and also in preserving the backing side of the blades from small pits due to dezincification. We are still experimenting with various coatings for this purpose but have not as yet found one that is completely satisfactory.

Captain Guy Chadwick, U.S.N., Member: Mr. Ffield is a modern pioneer in bringing designing engineers closer to the nature of the materials of their designs. His sense of perception enables him to view the phenomena of materials with a clarity which promotes simplicity of understanding. He fosters a pleasant acquaintance between the designer and his materials in such a way that the designer feels them to be old friends. The designer becomes more comfortable in his knowledge and understanding of the capabilities and limitations of materials than he would feel if he closed his eyes and followed the principle: "if you don't see it, it will go away."

In the observation of surface corrosion, the casual eye is drawn toward the corroded place, the victim of attack. As a result, much time and money have been spent in doctoring the victim in an attempt to prevent further deterioration by the local application of palliatives.

In the article under discussion, the eye is diverted from the anodic victim to the cathodic aggressor. It is then shown that the aggressor overcomes the victim by advantage in size. The question resolves itself into one of relative areas of the cathode and the anode.

Thus, it becomes proper to decrease the area of the cathode by the removal of cathodic material or by covering it as with paint. Conversely, it may be useful to increase the bare area of the anode by the addition of anodic metal for the specific purpose of wastage.

An attempt to eliminate corrosion by painting the anode begs the question because paint technology as yet has failed to provide an impervious membrane. A slight imperfection in the coating of paint on the anode exposes an area too small to resist the corrosion attack of a large cathodic area. Accelerated local corrosion is invited.

Some success, at high cost, has been had in affording an impervious protective coating to a limited area by the application of a rubber or metal sleeve to the outboard section of propeller shafting. But here again we are too familiar with the deep pits and grooves which result from small discontinuities in the sleeve.

Examples of the successful use of large anodic areas are many. In earlier days, old anchor chains were placed in hot wells in order to distribute the total corrosion over larger areas. When monel metal condenser waterbox heads were first used in naval vessels, accelerated tube corrosion occurred until the relative area of anode to cathode was increased by coating the cathodic heads with tin. The writer in company with many others has arrested corrosion in salt water cooled heat-transfer apparatus by adding more zincs. That a substantial increase in the total wastage of zinc did not occur is additional evidence that the rate of electrolysis is a function of the exposed cathodic area as well as the exposed anodic area. In the light of the article under discussion, it is likely that the use of large bare steel areas instead of zinc would have been effective.

The lack of permanency of a coat of paint is to be noted. This characteristic was brought forcibly to the writer's attention when he was assigned as Materiel Officer of the Atlantic Reserve Fleet for the purpose of preserving the naval vessels of World War II for future use. When the crews were detached and the ships no longer had a large source of manpower for continual chipping and painting, coats of paint exposed to the weather exhibited their temporary nature. Experiments with the products of modern paint technology showed some useful improvements, but not total cure.

It is noted that the thickness of a coat of paint is one measure of its life expectancy. But, during application, paint tends to brush off or flow from high spots and edges. This characteristic is not helpful in the painting of underwater surfaces, where high spots and edges also induce local high velocity of sea water flow.

Mr. Ffield remarks that the corrosion of ship bottoms has followed a cyclic pattern over the years. It is noted that a cyclic pattern is common in engineering applications where perfection of performance is not attained. A change is made for the purpose of improvement. The change may be to a method which was previously changed for the purpose of improvement. The occurrence of cyclic phenomena points the advantage of keeping engineering records as a safeguard against the errors of the past. This advantage is evident in the Navy Department specification system in which each specification is supported by a development file. The study of such a file will help point the relative advantage of the continuation of present painting methods, the development of new methods, or the reversion to red lead which has quite recently been suggested as the best for priming hull surfaces.

Mr. J. V. C. Malcolmson, Member: *Some aspects of ship bottom corrosion.* This paper is not only a very clear and interesting documentary report in regard to bottom corrosion, but is also a concise history of the problems which those interested in deep-sea vessels have had to face since the introduction of iron shipbuilding. One might add that it is also a good example of how history repeats itself. I think that the Society is to be complimented on having chosen an author who has access to the practical side of the subject, and at the same time understands thoroughly the technical side of a difficult problem and can present the latter in such a way as to be readily understandable by the layman.

Pitting corrosion due to turbulent flow, galvanic currents, etc. Turbulent flow in way of stern frame and rudder, in some cases, causes corrosion as a result of galvanic currents flowing from the steel to a bronze propeller. Unfortunately, on a new ship there is no known method of determining just where protection will be required around the stern frame or rudder. Because of this, zinc plates are "sprinkled" around in various places, each designer or superintendent engineer having his own ideas as to where they should be located. After six months' trading, however, there is usually indication of where the attack will be most severe. The author apparently does not feel that zinc plates are the answer to this problem, and it would be of interest to learn if he has seen or conducted any experiments with rubber coatings in way of these corroded or eroded spots around the stern of a vessel which, while not always of a serious nature, are constantly recurring and involve continuous outlay in repairs, such as fitting so-called soft iron protection plates, zincs, or chipping and building up with electric welding.

While on this subject, can the author tell us why, if experiments prove conclusively that magnesium is a more positive protection against cathodic attack, we continue to use zinc; and would he confirm that, if magnesium were used in place of zincs, it should not be coated with paint?

We know that coatings of neoprene within large sea valves have proved satisfactory where erosion

and cavitation were prevalent; but in the case of the sea valves these rubber coatings are heat treated or vulcanized, and such a procedure would not always be practical in the short time available while a vessel drydocks for bottom painting, coupled with the other difficulties which would arise in setting up a suitable heating unit in the dock for baking purposes.

Regarding underwater welding and velocity corrosion, I think a big percentage of our troubles with defective welding is due to the turbulence caused by the flow of water over rough-finished welding, the attack being accelerated in cases where the hand welding is undercut due to an inefficient deposit of the welded metal.

In an endeavor to overcome this trouble, we have issued instructions that an extra coat of paint is to be applied to all welded seams, while the vessel is on the drydock for regular painting. This is accomplished by having the painters wire-brush the welded seams, and apply a coat of paint prior to coating the large flat surfaces. It is interesting to note that machine welds, probably due to their smoothness, do not appear to be susceptible to velocity corrosion. For similar reasons, I think the flush finished rivet with a good countersink is preferable to the rivet with a heavy or conical point, which, incidentally, adds nothing to the strength of the construction.

Pitting corrosion due to stray currents. In Figure 8, we are shown examples of the white deposits resulting from stray welding currents. The author states that these deposits are in some cases caused by the heat from welding of an interior member, causing the paint to deteriorate. Is it not possible that the cause is due to the welding heat cracking the mill scale on the outside shell plating, thus leaving a strip of metal exposed to local electrolytic attack, because the mill scale in the vicinity is still adhering?

Galvanic corrosion due to the presence of mill scale. Figure 11 is captioned as "Shrinkage" from welding deposits. Does the author not consider the cracked mill scale in this case may be due to expansion of the parent metal which caused the mill scale to crack off in the immediate vicinity? The similarity between the photograph (Figure 11) and the magnetic field which can be made visible by iron filings on paper over a magnet is rather striking, as both seem to show curving lines of force which may indicate the kind of gravitational field which may exist around all deposited weld metal.

It is hard to understand why, if in 1870 shipbuilders and naval architects were aware of the deleterious effects of mill scale, we persist, seventy years later, in assembling the hulls of vessels with this dangerous coating still adhering to the parent metal. A stockpile of steel plates, racked in the shipyard for, say, eighteen months prior to assembly, seems to be a thing of the past and no longer practical.

The only methods to insure the removal of mill scale are to pickle the plates or sandblast at least the outside hull of a new vessel. In my opinion, this should be a definite requirement in specifications for new buildings. Further, if pickling is adopted prior to assembly, I think the welded and riveted joints, after erection, should be sandblasted prior to painting. In this way, the scale and surface inclusions which form on welding and riveting would be removed.

Rotary wire-brushing is not to be depended upon, as cases have been known where, with the best intentions, the mill scale surface was polished to bright metal, but the scale itself was not removed. Contrariwise, if the steel manufacturers can evolve a method whereby the mill scale can be made to adhere indefinitely to the parent metal, perhaps our corrosion problems would be over!

Would the author care to comment as to whether any thought has been given to requesting the steel manufacturers to control the finishing temperatures of steel plates to the extent that mill scale would be more readily removable? Maybe the amount of steel involved for shipbuilding purposes would not be of sufficient tonnage to warrant this requirement; on the other hand, it might be worth paying an extra to obtain such material.

We had a vessel constructed in a southern port, where the material, after being fabricated, showed no signs of depositing the mill scale even after six months on the stocks. This, in part, was probably attributable to the ideal weather conditions which prevailed, with temperatures varying but a few degrees. However, prior to launching, we decided to have the vessel completely sandblasted, all mill scale removed, the hull thoroughly coated with three coats of red lead and two coats of anti-corrosive paint. Subsequently, we drydocked before commissioning and applied the anti-fouling and boot-topping paint, and then drydocked in four months and again in six months. This has given us a good underwater body of paint. The vessel, since commissioning in 1949, has been trading in tropical waters exclusively, and when examined in August last, no corrosion or pitting had been found.

Finally, I think we would all be interested to know why steel which has been sandblasted has a tendency to blister, if painted thereafter in the old conventional manner; and why a wash coat primer or phosphoric acid wash eliminates this tendency to blister.

Mr. Raymond P. Devoluy, Associate: This excellent paper is most timely. Mr. Ffield is to be congratulated for his keen insight and ability to see through the mass of conflicting information which has been presented to explain recent ship bottom corrosion failures. This discussion is given to present some of our data and observations on the role of paints in ship bottom corrosion as they relate to points presented by Mr. Ffield.

Effect of impermeability on performance of paint coatings. Mr. Ffield mentions the low impermeability of many paint coatings. Most conventional bottom paint films, particularly those where alternate coats of anti-corrosive and anti-fouling are built up on the ship's bottom at frequent dockings during the early life of the ship, have very low impermeability to water. This practice can cause trouble because there is no effective barrier coat between the anti-fouling paint and the steel hull.

The use of paint coatings of high impermeability

is not new to shipowners for there are many vessels that had four coats of the good old No. 1 red lead applied to their bottoms before any anti-fouling paint was applied. This type of paint, when allowed it's long drying time, and applied at the proper film thickness, constitutes an effective barrier to the passage of copper ions through the primer film. The newer types of bottom paints are able to accomplish the same result at lower film thickness and with drying times measured in minutes instead of hours.

The multiple coat vinyl systems are an example of paints that have high impermeability to water. A simple demonstration of this was made recently during some cathodic protection tests. Five mils of such vinyl paints were able to confine the corrosion of magnesium anodes immersed in sea water to those areas of the anodes where we wished the corrosion to occur.

The role of anti-fouling paints in ship bottom corrosion. Many students of ship bottom corrosion have at one time or another found metallic copper deposited on the bottom plates. This copper comes from the copper ions leaching out of the anti-fouling paint and migrating through an inadequate anti-corrosive paint film. When this copper deposition occurs, it invariably causes severe pitting. It is for this reason that maintenance painting on ship bottoms should concentrate on building up the anti-corrosive to its proper thickness over any bare areas before any anti-fouling is applied. We know of no anti-corrosive paint which will perform this function satisfactorily when applied to bare metal in one coat.

Along the same line of reasoning, it is advisable to build up a highly impermeable anti-corrosive system when the ship is constructed. Care must be used in selecting an anti-corrosive paint system which does not check or crack when applied at the film thickness required for high impermeability with that paint. Naturally, the anti-fouling paint must be compatible with the anti-corrosive system both as to adhesion, and film contraction, and expansion.

In discussing galvanic corrosion due to anti-fouling paints, Mr. Ffield cites the work of several investigators who found that the higher the amount of copper oxide in the anti-fouling paint the greater will be it's cathodic effect on the bare steel. We will agree that this seems to hold true for the conventional coal tar-rosin vehicles which are the basis for most traditional anti-fouling paints, but we have rather conclusive data that an anti-fouling paint formulated so as to result in a film of reasonably good impermeability will have much less cathodic effect on the steel hull even though this paint contains three times more cuprous oxide toxic than the more permeable conventional paint. We agree that the galvanic corrosion caused by anti-fouling paints is not likely to cause much trouble on properly painted new ships. The anti-corrosive prevents it. The danger lies in using an "aggressive" anti-fouling paint in repainting work where the anti-fouling paint may be applied to bare metal areas or spots poorly insulated by only one coat of anti-corrosive paint.

The role of bottom paint in mill scale corrosion. When we first introduced the vinyl ship bottom paints some 4½ years ago, we were surprised at how often we were offered new plates, inserted in an old hull, for a test patch. These plates usually were not sandblasted free of mill scale and hence, as Mr. Ffield explains, they became the cathode to the surrounding bare steel. Such plates would always give paint trouble with any paints based on oils or other binders that do not have sufficient alkali resistance to withstand the alkali generated at the cathodic new plate. We were fortunate that the vinyl coatings are outstanding for alkali resistance and hence our tests performed very well. Apparently, Mr. Ffield's preaching has done some good as we now find that the sandblasting of new plates inserted into old hulls is commonplace.

Table III in Mr. Ffield's paper contains a wealth of information. The results of these studies demonstrate the value of vinyl coatings, and also of two other paints of high impermeability, when painting over partial mill scale surfaces. It is very interesting to note that the good paints have performed as well, or better, on the wire brushed or on the partially ground panels, as they have on the sandblasted panels. Our test work suggests that this is due to the greater surface roughness of the sandblasted panels and that the film thickness of the paint film must be ample to provide the required minimum thickness over the "hills" in the sandblasted surface.

We have pointed out previously the importance of a highly impermeable anti-corrosive layer to prevent accelerated corrosion of the steel hull by the anti-fouling paint. This same anti-corrosive barrier coat plays an important part in our scheme for reducing or eliminating the effects of mill scale corrosion. We are in full accord with Mr. Ffield that sandblasting or pickling are better and safer procedures than to rely on maintaining a perfect paint system on the bottom of a ship. There are occasions, however, when the cost of sandblasting does not seem justifiable to the owner of a new ship. In such cases, we feel that the problem can be solved through the use of paints of high impermeability. When the ship's bottom is coated with a vinyl system applied to its proper film thickness, there is very little of the hull surface in contact with water. Mill scale corrosion cannot progress in the absence of an electrolyte and so we found that two steel fishing vessels, hand wire brushed to remove loose mill scale and coated with a well-applied vinyl system, have experienced no pitting for three years.

This leads us to Mr. Ffield's justifiable concern as to what happens when such a vessel suffers a grounding or other abrasion that removes some of the paint coating. We recently inspected a new supertanker whose bottom was power wire brushed and then painted in the above manner. This vessel had been in the water for six months and had suffered some extensive paint removal on launching, but we were unable to find accelerated corrosion in the bare area. An explanation for this good condition is that by far the bulk of the ship's bottom plating was out of the galvanic corrosion circuit because of the high impermeability of the bottom paint. The paint-free area

of bare steel and exposed mill scale was apparently in such a ratio that aggressive corrosion did not materialize.

Since one of the major problems is removal of paint by abrasion, it follows that the most abrasion-resistant paint, whose impermeability is also high, should be used on vessels that are not being sandblasted. It is also important that the paint system resist undercutting away from the abraded areas. We do not know at this time how these relatively new paints will perform on mill scale ships through the years, but all the data that is available shows no cause for concern.

The author mentions that there have been no cases of accelerated corrosion on pickled or sandblasted ships even when areas of paint have been scraped off. The ships in this category which we inspected were painted with highly impermeable paints and it was noted that weld, rivet, and plate corrosion was abnormally slow. This again can be attributed to the insulating effect of these paints on the remainder of the underwater area. Similar observations have been made by other corrosion engineers working with glass coatings and with rubber coatings on sandblasted steel panels.

Edge corrosion. As Mr. Ffield points out, welds, rivets, and other sharp-edged areas on a ship's bottom are the most frequent places for severe corrosion. We have observed that very quick drying paints are unusually effective in preventing corrosion on rough or sharp-edged surfaces. We think the chief reason for this success is the ease with which a paint film of the proper film thickness can be built up over the hills and in the valleys of such surfaces. It is a matter of record that some supertankers sandblasted and then painted with quick drying vinyl coatings have been markedly free of weld and rivet corrosion.

Washcoat primer. It is gratifying for us to see Mr. Ffield's enthusiasm for the washcoat primer as an after sandblasting treatment. We check his experience completely, not only on bottoms but also on boottops and topsides. This primer started out merely as the first coat in the vinyl paint system and has now proved itself to be very valuable as a priming coat for conventional paints. Its success seems to be due to the extraordinary adhesion it develops to bare metal. Its adhesion to mill scale is also very good.

Cathodic protection. There is much work being done on the combined use of paint and cathodic protection. This is a rather difficult problem because most of the paints now in use are seriously and rapidly degraded by the alkali generated by the cathodic protection. To be satisfactory, a coating for this purpose must be alkali resistant and possibly also have good electrical resistance. Furthermore, the potential must be reduced to prevent formation of gas blisters. It is hoped that current research work will disclose how these two basic corrosion prevention techniques can best be used jointly in order to realize the advantages of each.

Paint application. We very much appreciate the author's warning that ample time should be allowed for adequate painting on new bottom plates. This also applies to any ship bottom that is being sandblasted or scaled to bare metal. The newer types of bottom paints are engineering materials and their performance is known. The shipyards want to do good application work and many owners are now investing the time and money required for good bottom protection. This sort of investment will pay large dividends over the life of a ship.

Mr. George W. Place,* Visitor: This very informative paper by Mr. Ffield has clearly shown that his painstaking efforts, over a considerable period of time, have resulted in some exceedingly worth-while methods for the purpose of ship bottom protection.

The paper deals mainly with the ship's bottom and it would be of further value if the author would enlarge on the scope of his paper to include the strakes between the light draft and to slightly above the deep load waterline. Records of cargo vessels in the coal trade indicate that the strakes between wind and water, so called, may be wasted down as much as one-fourth of the original thickness in 24 years of service. With the added wastage of the plates inside, as shown by drilling, these strakes sometimes are found to be about 40 per cent of the original thickness and, of course, in such cases the entire renewal of these strakes has been necessary.

The author has explained the phenomena of mill scale corrosion and has cited cases where this form of corrosion has resulted in serious bottom deterioration. Although he states that the surest way of avoiding mill scale corrosion is to pickle or sandblast the plates before painting, he also includes a statement to the effect that, if the mill scale is reduced to safe limits by weathering and if the paint is built up to an impervious thickness and frequent examinations are made, there will be no real trouble. On this latter statement hangs considerable hope for the shipowners to lessen at least the early corrosion troubles and many owners have made it a rule to carry out frequent drydockings and recoating on their new ships, which has proved to be good protection with minimum cost.

It has been shown by actual cases of new ships that active pitting has been arrested after several recoatings have been given the ship. As an example, we recall a new passenger and cargo ship built in 1939, in which the building time on the ways was approximately twelve months. The mill scale was allowed to weather off the plates with final power brushing in the conventional manner. When the vessel was first drydocked a considerable amount of pitting of bottom rivets was noted. There were also spots on the shell where building way shores had been in contact with the shell and some pitting was also noted in way of internal welds where the paint had apparently been affected by the heat of welding. While of considerable concern it did not appear necessary to deal with these areas at the time, other than to clean off the hull thoroughly and recoat. Upon examination nine months later no further corrosive action had developed and nothing further was done at this time except cleaning and recoating. This

* American Bureau of Shipping, New York.

vessel is now eleven years old and recent examinations have not disclosed any noticeable evidence of the early corrosion trouble.

The author has discussed the role that the type of paint and the paint system employed plays in the satisfactory protection of the ship's bottom and we would like to emphasize the importance of proper selection of paint and application of same. As a matter of interest one of the eastern shipyards has forbidden the use of paint by their inspectors or counters for marking driven rivets for fear that the paint which may be used in marking may have a deleterious effect on the paint subsequently applied.

Mr. H. B. Benford, Associate Member: There is one phase of hull corrosion which Mr. Ffield has not mentioned and which is usually overlooked by both the ship operators and the repair yards in their rush to get the ship back into service. It has been the writer's observation that most scuppers, soil drains, and other overboard discharges are left unplugged during painting generally and almost invariably one or more of these will allow water to run down the shell and prevent proper adhesion of the paint in their path.

In one particular case a ship of slightly less than thirty years of age was brought into dry dock to repair a leak which had developed in the side shell just above the turn of the bilge. Examination showed that the leak had developed owing to the presence of a 1-inch overboard discharge from the refrigeration machinery. This discharge was located just below the sheer strake of shell and over the years had been allowing a trickle of water to run down the side leaving a clear line of deterioration which finally ate through the shell as previously stated and required portions of two different strakes to be cropped out and renewed. It is easily conceivable that conditions such as this might cause a complete hull failure.

Mr. Herman S. Preiser, Junior Member: Mr. Ffield's paper is very thorough and extremely well presented. There are a few additional comments that may be worthy of inclusion. The employment of suitable current densities in the cathodic protection of a ship bottom will not only deposit a calcareous coating on the hull, but, prior to the coating formation, the electrolytic reaction at the cathode will tend to lift and dissolve the scale and adherent rust layer on the steel surface.[1,2] Theoretical chemical equations of this reaction have been developed[3] which attempt to explain the conversion of an insoluble rust layer to a readily soluble composition at the cathode. It is believed that the formation of hydrogen gas at the cathode materially aids in "blasting" the rust and scale layer off the metal surface. Many successful experiments have been carried out on this combined descaling and electrocoating technique.[4]

The Newport News Shipbuilding and Dry Dock Company, in 1940, utilized impressed current methods of cathodic protection for the preservation of the underwater portion of the hull during the fitting out period[5]. This was done to protect the hull from rusting and pitting corrosion resulting from the existence of *holidays* in the paint system and from the presence of cracks in the cathodic mill scale areas. One experiment was carried out on the *President Adams*, where two weeks prior to drydocking, the cathodic protective current was discontinued. The white deposits of calcium and magnesium salts slowly dissolved from the hull and, when docking was finally completed, only a superficial, light, even rust layer was observed on the hull.[6] No deep pitting occurred. The ship was then considered to be ready for a conventional paint system.

A bit of elaboration on one more point would be in order here. Paint blistering is always a difficult problem when cathodic protection is applied in conjunction with paint systems. Tests at the Engineering Experiment Station at Annapolis, in 1943, indicate that cathodic voltages above 0.4 volt are destructive to conventional oil-based ship bottom paints.[7] There is evidence from preliminary observations that the phenolic resin type paints may be able to sustain higher cathodic voltages. PH and hydrogen evolution are functions of cathodic voltage.

Another proposal undergoing some serious consideration is the possible total elimination of the paint system on the submerged portion of the hull with the reliance on a cathodically maintained electrocoating for complete protection.[8]

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Captain Henry A. Ingram, U. S. N., Member: This paper is a welcome assembly of the circumstances which cause corrosion problems of the immersed portions of a metal hull. The causes and effects are clearly and understandably described for the benefit of those who find the peculiarities of corrosion phenomena perplexing. The individual responsible for the maintenance of a ship's underwater parts can now systematically check off the possible causes of an outbreak of corrosive pitting and effect a remedy before too much damage is done. Better still, he can take preventive measures with assurance that emphasis is being placed on what is important.

From the background of this paper, it may be appropriate to summarize the requirements of an ideal low-cost anti-corrosive, anti-fouling system.

(I) *Surface preparation.*

(1) There seem to be no grounds whatever left to

question the essentiality of removing mill scale. Pickling is presently the cheapest and best method for new work, especially when one considers that it cleans both sides of the plate in one operation. It is just as important to eliminate mill scale in the bilges and tanks as on the exterior of the hull. It also serves to insure that there is no mill scale under a faying surface to the end that the adjoining parts are more intimately connected.

(2) If replacement of the coating system over part or all of the underwater body is required, another method of surface preparation which will best insure adhesion of subsequent coatings is necessary. Has this adhesion problem really been studied in the light of recent scientific developments? In this connection, a paper entitled "Fundamentals of Adhesion" from the Organic Plastic Section of the Bureau of Standards in the September issue of *Mechanical Engineering* is of interest in outlining the underlying principles of adhesion. To date, sandblasting has proved most practical, but it is an expensive and messy job to do, to clean up after, and may involve accelerated wear and tear on the drydock machinery.

(II) *Primer.*

Should a washcoat primer be used? The evidence cited points strongly to its value. But when? The whole system of subsequent painting must be reviewed to determine this point. Is it effective over the period of exposure before the vessel is ready for the final painting? If not, an after-pickling paint may be required. An after-pickling paint coat protects the steel in the storage racks, makes it cleaner to lay out and to fabricate, and keeps a cleaner ship throughout the building period. If of a light highly reflective color, the illumination and hence the working conditions should be improved. But is this after-pickling paint a suitable base for the application of the service bottom painting system? If not, it will have to be removed at a later time. By sandblasting, with its attendant confusion and mess? The ideal would be a washcoat primer that would last through to the pre-launching painting with perhaps a little touching up as needed.

(III) *Anti-corrosive Layers.*

The properties of the anti-corrosive layers should be in order of importance:

(1) 100 percent adhesion to the hull.

Mr. Ffield's paper clearly shows the danger of accelerated corrosion where small areas of anodic metal are exposed. If the washcoat primer assists in promoting adhesion, all well and good. If not, it is a weak link in the system.

(2) A smooth surface.

The Navy's hot plastic system is justly criticized for the high initial skin friction resistance.

If a smooth job is to be achieved, a smooth undercoat is a necessity. The degree of permissible roughness should be specified in measurable terms.

(3) A high degree of adhesion to the anti-fouling coat which will follow.

(4) Adequate and uniform electrical resistance to galvanic currents after long submergence.

This is primarily a question of film thickness.

Thick films have higher electrical resistance but they are often less smooth, weight more, and cost more in materials; and, if applied in successive layers, cost much more in time and labor cost of application.

(5) Low permeability to penetration of sea water. Film thickness is important here also.

(6) An ingredient inhibiting corrosion of steel in the presence of sea water.

(7) A contrasting color to the surface it is painted over to insure even coverage by the painter.

Perhaps the anti-corrosive should be the hot plastic formulation applied once for a long life, and the anti-fouling layer alone recoated at each docking.

(IV) *Anti-Fouling Surface.*

This application may be compared to a metering mechanism which releases or exudes toxic at an economical rate just more than barely sufficient to repel the attachment of marine organisms. There are two accepted types of mechanisms which may be called:

(a) The "wasting surface" type.

(b) The "permeable matrix" type.

The "wasting surface" type is more commonly known. If skillfully formulated, the matrix wastes away through erosion and dissolution at a rate comparable to the exhaustion of the toxic particles, thus exposing lower layers of toxic. The thickness of film required depends on the length of time that anti-fouling effect is desired. It may be expected that the rate of erosion will bear some relation to the length of time and the velocity at which sea water passes over the exposed surface. The rate of dissolution would be related to the temperature and possibly to the composition of the water.

The "permeable matrix" type carries a high loading of toxic particles in an insoluble matrix. As the toxic dissolves, open channels down into the film develop. If toxic particles are in contact with one another then, theoretically, they may all be considered ultimately available. The strength of the matrix makes this type of paint desirable where erosion is a major influence, as on fast vessels, or on those vessels which are never at rest for long periods in fouling waters.

The ideal anti-fouling paint should have these attributes in order of importance:

(1) It must adhere to the under layer.

(2) It must repel attachment of marine fouling organisms under the most severe conditions likely to be met.

(3) It must be sufficiently resistant to the erosion of water for the service encountered.

(4) It must be readily renewable without the necessity of removing intact anti-corrosive layers underneath.

(5) It should be effectively smooth to some prescribed standard. Since the surface which is presented to the passing flow of water is not the paint itself but the layer of marine slime which attaches to the paint, the best paint is the one which will encourage that kind of slime film which has the least frictional coefficient.

(6) It should have a contrasting color when applied to the under layer.

(7) It should be applicable under all conditions of weather.

(8) It should withstand abrasion such as grounding, contact with piling, barges, alongside, etc.

(9) It should stand up to the sun, wind, and water exposures of the boot-topping area and its appearance in this area should continue to be attractive after long periods.

(10) It should be low in cost of application using simple procedures and equipment.

(11) It should not contain strategic materials.

(12) It should be low in material cost.

Dr. Alvin C. Purdy, Associate: Commenting on Mr. Ffield's interesting and valuable paper, we offer the following notes based on field surveys and related hull corrosion studies dealing with the selection of storage sites for surplus vessels following World War II. These surveys were conducted in 1945 and included nine proposed sites; three along the South Atlantic Coast, three along the Gulf Coast, and three on the Pacific Coast. Water conditions at these several sites varied widely, some being in lakes or on rivers in essentially fresh water and other being in bays where the salinity approached 90 percent of that of sea water.

Our study of the corrosion problems involved in the choice of storage sites led us to the conclusion that the most important considerations from the standpoint, both of corrosion and the maintenance of protective paint films, were the salinity and dissolved oxygen concentrations at the proposed locations and whether there was evidence of stratification or periodic variation in these salinity and dissolved oxygen concentrations. There was, of course, the possibility of the specific corrosive effects of local trade wastes, and these were given supplementary consideration.

A study of salinity concentrations and corresponding corrosion rates would suggest the desirability of choosing lay-up basin sites where the water is essentially fresh and particularly to avoid brackish waters running in the neighborhood of 20 percent full sea water salinity as these brackish waters are often less desirable than sea water. This conclusion is based not

only on the increased corrosion rate of exposed metal surfaces in water of high salinity but also on the failure of protective coatings in saline water, particularly in waters having sufficiently high salinity to support the growth of barnacles and borers.

Corrosion and failure of protective paint films are also accelerated by potential differences resulting from stratification or periodic variation in salinity or dissolved oxygen concentrations. The stratification of dissolved oxygen was reported to be an important factor in a study of the corrosion of Panama Canal locks and was also considered to be significant in the corrosion studies made on ore vessels which were laid up in the Great Lakes as the result of the economic conditions of the early thirties. The hull corrosion rate on these ore vessels in normal operation, with lay-up only during the winter months, is very slow, but when the lay-up period was extended through two or more summer seasons, it was found that the pitting rate rose to about 1/16 inch penetration per year.

In the course of our field surveys, we found several cases of wide variation or stratification of salinity and dissolved oxygen conditions between the surface (2 feet below the actual water surface) and subsurface (15 feet below the water surface) samples. For instance, on the Neches River near Beaumont, at the time of sampling, the surface salinity was 10.3 percent of sea water salinity while the subsurface salinity was 20.2 percent. The corresponding dissolved oxygen saturation percentages were 62.2 percent and 43.3 percent, respectively. Since a potential difference of some 9 millivolts is developed between fresh water and sea water, an appreciable potential difference might be expected between any waters having a relatively wide variation in salinity concentration.

Certain conclusions were drawn by us as the result of our field surveys and study of analytical data bearing on the relative advisability from a corrosion standpoint of the choice of the proposed sites, but, of necessity, such conclusions were based on theoretical considerations, limited personal experience, and observations supplemented by the opinion of consultants, and the very limited literature on the subject. As many of the sites studied were later used for the storage of surplus vessels, we believe that a very interesting and valuable paper could be prepared for presentation to the Society, if the technical personnel of the government department charged with the maintenance of these surplus fleets would make a study and report on the hull corrosion actually experienced in these laid-up fleets.

Captain J. H. Rodgers, U.S.N., Member: This excellent paper is a valuable contribution to the knowledge of the practical aspects of ship bottom corrosion. Although many of the examples cited by the author appear to have been taken from commercial practice, a number of the corrosion problems described are also encountered in the Navy.

Because of the lighter scantlings employed, corrosion is a more serious problem for the Navy than for private shipbuilders. In common with them we have recognized that mill scale is a source of serious corrosion. We have, therefore, always required and enforced to the maximum degree consistent with wartime delivery schedules, that all mill scale on structural members be removed by pickling, sandblasting, or flame cleaning before plates are erected. Currently, this requirement is rigidly enforced.

The Navy's experience with underwater paints and particularly with the vinyls and the wash primer pretreatment corroborates the author's experience that the type of paint used and the nature of the surface to which it is applied are important in preventing corrosion. Surface preparation by sandblasting to remove all traces of corrosion products is universally used on underwater hulls on ships in service. We have found however, contrary to the author's data in Table III, that on a sandblasted surface, and regardless of the nature of the inhibiting wash (phosphoric acid or sodium dichromate-trisodium phosphate) Navy anti-fouling paint systems have remained in good to excellent condition for periods ranging to five years on ships in the Reserve Fleet. (Condition observed at regular docking interval.) On ships in service, standard Navy underwater coatings applied to sandblasted steel are regularly found to be in good condition after 18 months to two years of service. We also concur in the beneficial value of the wash primer (developed, incidentally, under Navy contract with the Bakelite Corporation). During the past year it has been used as a standard treatment for all underwater painting at three shipyards and use will be extended in the near future to all Naval Shipyards.

We have also been keenly interested in cathodic protection of ships' hulls in both the active and reserve fleets. Installations of high purity zincs, in which the zincs have not been confined to the stern areas, have been made on a number of ships in service. Similar installations with magnesium anodes are planned. Protection of hulls of reserve fleet ships by the use of both magnesium anodes and impressed current has also been initiated. It is hoped that this form of protection on reserve ships will reduce the necessity for supplemental protection of the hull by zincs and replaceable sleeves at sea chests.

The author has made no mention of several ship bottom corrosion problems which have caused the Navy much concern. The waterline areas have been found to be principal locations of corrosion attack. World War I destroyers, for example, when docked for refitting for service in the second war were found to have the bottom plating intact; however, many required installation of a new strake of plating completely around the waterline. The problem is also acute on ships now in service as well as those in the reserve fleet. These areas require more attention than the underwater hull. Test application of vinyl coatings have shown that they are superior to the present paints and it is expected that vinyls eventually will be adopted as standard.

Bronze sea-chest valves are another source of corrosion. Since there may be up to one hundred sea-chest valves on a large ship, arresting corrosion of the steel hull in the vicinity of each of the valves is a difficult task. Replaceable steel protector sleeves which are inserted in each sea opening are providing

an effective means of reducing corrosion from this source.

Mr. F. N. Speller,* Visitor: Mr. Ffield has given a useful summary of the factors that affect ship hull corrosion, particularly in regard to the deleterious influence of mill scale, on which I am in complete agreement.

The corroding potential due to variations in the metal itself is so small, compared with that due to contact effects and other factors external to the metal, that it may be said pitting is caused, or prevented, by control of the surface environment of the metal.

Mill scale varies in composition and adhesion, and is difficult to control in the rolling operation. It is *primarily* responsible for the couples that cause pits to form at anodic areas where the scale is broken. The rate of pitting increases as the pit holes become deeper, due mainly to the added potential of the differential oxygen cell. Differences in aeration of the anode and cathode areas is one of the common causes of pitting. Shortly after a pit is started, the corrosion products usually form a mound, or tubercle, over the corroding anode, that shields the anode from oxygen in the water and thus *increases* the corroding potential. Laboratory tests and experience show that periodic removal of rust tubercles minimizes, or prevents, serious pitting. An experience with corrosion of bottoms of ore carriers on the Great Lakes showed that these bottoms (although often partly devoid of paint) did not pit seriously until the ships were laid up in harbors during the 1932-1933 depression. Previously, many of these ships were given a run in slush ice in the spring, to clean the bottoms. This operation, and the scouring effect in shallow harbors, kept the bottoms fairly clean in regular service until the boats were laid up in harbor water; then the metal was pitted ⅛-inch deep in two years.

The hidden menace of mill scale under paint as Mr. Ffield has pointed out, should encourage the removal of all scale, by pickling or sandblasting, before painting.

The deposition of copper from anti-fouling paints on clean steel has been demonstrated, and has been shown to increase corrosion unless the anti-fouling paint is separated from the metal by at least two coats of paint. Therefore, particular attention should be given to securing uniform and adequate anti-corrosive painting of descaled hulls.

* Corrosion consultant, Pittsburgh, Pa.

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Mr. C. P. Larrabee,* Visitor: Mr. Ffield's paper is a distinct contribution to the literature concerning this subject which is of so much interest from both an economic and a national defense viewpoint. In this country, we are to prone to consider first rather than ultimate cost; and, therefore, we frequently have not paid sufficient attention to the details of applying the first paint system to steel structures. By a consideration of the many factors listed by Mr. Ffield, the ultimate cost of protection of steels exposed to water might be decreased substantially.

There are two minor points upon which a few comments might be made. In the first full paragraph on page 33, the author discusses the white crystalline compounds of magnesium and calcium that are found on cathodic areas of steel. He calls this product "residual salts." We think the use of this expression is unfortunate as "residual" usually brings to mind the product of evaporation. The term "calcareous deposits" might aptly describe the product of the cathodic polarization of a metal in sea water.

The other point has to do with the author's discussion, in paragraph 6, column 1, on page 42, of the mechanism of removal of mill scale by corrosion. He states that "there is a tendency for the inner layer of ferrous oxide to absorb oxygen from the air and revert to the ferric form" (Fe_2O_3). We have examined many samples of mill scale that had been removed by weathering, and while it is true that there is a red-colored iron oxide layer on each piece, there is more black oxide than red. It seems to us more probable that the steel immediately adjacent to the inner ferrous oxide layer "rusted" and thus destroyed the bond between the rolling scale and the steel. As most rolling scales are divided into relatively small areas by hair-line cracks, and as the scale is cathodic to the steel, under most service conditions the latter would tend to corrode. Capillary would force moisture, such as dew (containing sulfur fumes from the air), into any minute cracks formed between the scale and steel by differential expansion, and corrosion of the steel would result. It should be remembered that, according to the generally accepted electrochemical theory of corrosion, atmospheric corrosion occurs only in the presence of a liquid.

Mr. T. P. May,* Visitor and Mr. F. L. LaQue, Associate: The author is to be complimented for his excellent discussion of problems which arise from corrosion of ship bottoms. He has presented a particularly valuable review of the difficulties which may be encountered when hull plates are not freed of their mill scale. Not many features of bottom corrosion have been omitted but we think perhaps some additional observations may be of interest.

In discussing the electrochemical nature of corrosion, the author refers to anodic areas as being more positive than cathodic areas. This choice of sign of potentials in the electrode potential series of metals is an arbitrary matter. Some workers do as the author has done and others prefer to call the anodic areas the more negative ones. Some times this difference in expression of potentials leads to a certain

* Research Laboratory, Carnegie-Illinois Steel Corporation, Pittsburgh, Pa.

* Corrosion Engineering Section, Development & Research Division, International Nickel Company, New York.

amount of confusion. Therefore, in order to avoid confusion among readers who may be referring to other literature on the subject, we think it might be well to point out that corrosion specialists usually consider anodic areas to be negative.

The author's discussion of the serious pitting and corrosion of rivets and welds when large areas of mill scale are present is a particularly valuable one. The problem which arises because of the presence of mill scale is one which is frequently overlooked as the author has pointed out. Some very interesting observations on this subject have appeared recently in an article by J. C. Hudson.[1] This paper is a valuable addition to the historical and technical review of the mill scale problem presented by the author.

In Figure 10 potentials between bare steel and copper and between bare steel and mill scale are indicated to be of approximately the same order of magnitude. The author concludes from this that mill scale is just as severe a cathode as copper when coupled to steel. He indicates in this particular case that the potential difference is of the order of 25 millivolts with the bare steel being the anode in each case. Our observations, especially in moving sea water, have indicated a much greater potential difference between steel and copper, this being of the order of 200 to 300 millivolts rather than 25. The low values of the differences in potential between bare steel and scaled steel and bare steel and copper and the similarity of these values suggests that the instrument used to measure the potentials permitted the passage of sufficient current to allow both the mill scale and the copper to become polarized to a potential only 25 millivolts more noble than the bare steel. Apparently under the conditions of this test, as well as other conditions that may be encountered in service, mill scale and copper have similar cathodic polarization characteristics so that under conditions of substantial current flow they would act very much alike as cathodes in causing galvanic corrosion of bare steel as has been observed in practice as described by Mr. Ffield in his paper and in some of the papers by other authors to which he referred.

The author has made a very interesting proposal concerning the role of galvanic anodes in reducing the corrosion of the hull bottom; namely, that the galvanic anodes are effective because they increase the anode area and thus reduce the intensity of attack on the bare steel. It generally has been accepted that any effectiveness of galvanic anodes must appear in the polarization of cathodic areas, such as bronze propellers. Our studies of polarization of metals in high velocity sea water clearly demonstrate that exceedingly large current densities are required to polarize metals in moving sea water. Because of this it is not likely that anodes of low activity, such as zinc, would cause polarization of bronze propellers. This proposal by the author therefore is probably completely true in the case of zinc anodes and partially true in the case of very active anodes such as magnesium.

In the discussion of potentials available at zinc anode surfaces it was pointed out that the potential of zinc varies with its purity. Perhaps it might be better to say that impurities of the usual percentages in zinc anodes (up to 1 percent) do not affect greatly the potential as such. More properly these impurities have an influence on the nature of the corrosion products which form as a crust or coating on the anode surfaces. High purity zinc (99.99 percent) develops a soft, non-adherent coating of corrosion products which has relatively low electrical resistance. In contrast, zinc containing as little as 0.2 percent impurities may develop hard, adherent coatings of corrosion products which have a high electrical resistance. Accordingly, after a short time as anodes, impure zincs become ineffective because of the high resistance of these corrosion products. Analysis of the corrosion products has not revealed any significant difference in their composition and it appears that the differences are physical in nature.

The author also has suggested that on certain occasions the potential of zinc can become more noble than that of steel. We have never observed this in sea water and actually doubt if this can occur in sea water. Schikorr[2] and Hoxeng[3] have reported reversals in the relative potentials of zinc and steel in other waters especially at elevated temperatures. Hoxeng has pointed out however that in the presence of chlorides it is extremely unlikely that zinc will ever become more noble than steel.

One more point concerning zinc anodes is of interest. It has been observed in some installations that new zinc anodes will produce currents which are great enough to remove paint from steel immediately adjacent to them. As long as the zinc is actively producing current, this causes no problem. But if the zincs appear to be of a composition which causes them to become inactive due to high resistance films of corrosion products, they no longer will be able to protect the surrounding areas of steel from which they have removed the paint film. A more active anode such as magnesium does not have the disadvantage of forming insulating corrosion products and continues to produce large current output. Because of the high current output of magnesium, it will cause a removal of paint from steel as mentioned in the case of zinc but after removal of the paint the magnesium will continue to protect the steel. In some cases it may be that magnesium will produce such large currents that its life will be too short. In such instances the magnesium will require current limiting devices to prevent its rapid consumption. Such devices can now be made available and therefore magnesium should have more consideration for this application.

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Mr. William Bennett, Member: Mr. Ffield treats this subject in a very practical straight-forward manner, and as he has had considerable experience of this annoying phenomenon his remarks are all the more worthy of our serious consideration.

He indicates that the nigger in the woodpile is mill scale corrosion, which occasionally becomes an epidemic the cause of which is obscure. I suggest the cause is due to indifference on the part of owners and operators in the care of the underwater surfaces of their ships. It takes a so-called "epidemic" now and then to bring to their attention the necessity of taking a deeper and more personal interest in the cleaning and recoating of the shell plating. Such care too would prove to be more economical in the long run when one considers the expense of scale removal by sandblasting or otherwise of the vessel on drydock, and the delay and expense of such drydocking.

He indicates the cure to be scale removal by pickling, weathering, sandblasting, or otherwise, followed by a wash-coat primer and the usual anti-corrosive and anti-fouling. There is no doubt that this is most important, and, if done, would reduce most if not all of our corrosion troubles. There are cases however where, with mill scale adhering in spots, we have no pitting of the plates but serious wastage of rivets (or welding), and in other cases where the rivets (or welding) are good and the plating pitted. I am sure the members will agree that quality of plates, rivets, and welding is still a most important factor.

In my opinion there is no single cure for corrosion. Each case presents a different problem and has to be studied individually, including such questions as the treatment of the plates at the shipyard (in regard to scale removal), the coating of the plates before and after launching, the incidence of drydocking, the vessel's service, etc. Even with all this information before one, we are sometimes nonplussed to finding that ships built at the same yard, apparently under the same conditions, and in the same service, are affected quite differently with regard to the corrosion of the underwater shell plates.

The important lesson to be draw from the paper, and I am glad the author has drawn our special attention to it, is the necessity of freeing the shell plates of all mill scale. The practice in many British shipyards is to pickle all the shell plates, and I understand this practice is becoming more general in the shipyards here. This is all the more necessary, since modern mills tend to produce a tighter scale due to faster rolling and controlled finishing temperatures.

This paper is a noteworthy contribution to a most elusive and annoying affliction to all shipowners, and our congratulations go to the author for a most interesting and informative paper.

Mr. C. Hastie, Member: The presenting of pertinent information on one of the oldest and most elusive problems to the shipowner breaks fertile ground that should summon much practical experience in discussion to enrich the author's instructive and valuable contribution to the Society's records.

Notwithstanding the large amount of careful research and consequent advancement of theories, the problems concerning corrosion of structures remains one of the most thankless tasks confronting the metallurgist.

If, in respect to ships, it was simply a matter of gradual wasting as shown in Table I, or as otherwise expressed, that the rate of deterioration on the average aggregate amounts to about 0.0045 per inch thickness of material per year, we could accept it and inevitably console ourselves by viewing our own human frailties.

However, it is not so, and in the same sense that we make periodic visits to the clinic to ascertain and check for condition, so the cause of accumulative corrosion—pitting and erosion, etc.—with due dilligence can be greatly minimized.

The statement on page 32, "It is most unlikely that stray current corrosion can occur when the electric currents are generated on a ship when it is at sea," will, I am sure, be concurred with, for the advent of wireless telegraphy and telephony years ago, necessitating in general the fitting of supplementary electric equipment on board vessels, did give rise to much conjecture respecting accelerated corrosion associated with rapid wastage of certain piping in lower reaches, and, it was said, the culprit had eventually been discovered. The theorizing, however, was completely discredited by exhaustive investigation which acceptably revealed other origins with attendent features which had not hitherto been considered, among them being the 'make-up' of the material itself and anti-fouling paints with varying copper content lending toward galvanic action rather than preventing it to which the author alludes on page 44.

The percentage of scrap metal used today in the making of steel is quite large.

Looking backwards to 1916 as a comparative relative reminder, and not too ancient at that, I remember quite well viewing thirty-year-old (pre-British) Japanese freighters that did not have a square inch of paint on their shells and not any corrosive-pitting discernible.

To vessels of more recent years, fitted with bronze propellers and dissimilar metal accessories, the special developed compositions of the purely insulating and sealing types applied at stern and lower counter have proved excellent deterrents against galvanic action by salt sea water as the electrolyte. I do think however, that the application of zinc slabs fill a void and have been very beneficial.

The author's suggestion that the use of magnesium as a functioning anodic element, and which under "test" experiment has shown up quite good, would I'm afraid prove expensive to the shipowner as the renewal periods would be of short duration and in the interim of necessitated extended drydockings to meet commercial emergencies, etc., the result might be damaging when having to rely upon the substance alone. However, an expression from the author in this direction would be welcome and of interest to many members.

When compositions are applied to a new vessel that has had her plating thoroughly weathered by the

seasons on the stocks during building, then effectively dry wire-brushed permitting the initial application of the composition to impregnate the surface pores of the plating, no better initiation or baptism is said to obtain.

As one superintendent of a fleet of large dry cargo vessels put it, "My only concern is with the keel strake as it cannot be properly cleaned and coated on account of the close proximity of the blocks necessary for adequate support of the vessel in drydock."

The author's reference, informing in respect to mill scale in the role of the "cathode," is quite convincing seeing that it is the element, under certain conditions, that is susceptible to the accumulating action.

There are instances where mill scale, having been found entirely intact on vessels of small dimensions, tended to disprove the contention and shed light in certain directions where the application of sheathing had been found beneficial.

The answer adverse to this, however, is: should the mill scale contain particles of carbon or cinder or other material electro negative to iron, the steel it is shrouding unfortunately becomes the corroding anode.

It is upon this basis that F. G. Burgis of the University of Wisconsin, presenting an analysis of the "Causes of Corrosion to Steel Structures" before the Western Society of Engineers, gave his explanation upon examining certain corroded and pitted material with areas of black oxide, etc., which had made the surrounding iron the anode.

It may be of interest to recall that in 1922, after the First World War, there was quite an epidemic of corrosion-affected vessels and in instances coming under personal notice the bilge strakes of plating suffered very badly.

Inquiries revealed that those plates which were shaped cold suffered more than the ones treated at the furnace prior to rolling. Some of the vessels affected had called at small obscure ports where the waters were more or less polluted by chemical drainage from manufacturing plants. Also the heads of the seam rivets (i.e., points) were noted to have suffered much more than those of the transverse frames in the region of the alternate load line areas. Metallurgical scrutiny disclosed the rivets to be heavy in carbon content and the structure of a marked strained nature, indicative of cold working.

No reference, it is seen, is made to internal bottom corrosion, which in the instance of riveted tanker vessels, in past years, has been quite extensive.

The introduction of electric arc welding, making for smoother and cleaner surfaces and greatly facilitating prefabricating methods in construction, is truly responsible for the improved physical condition we have today. However, on lower horizontal internal surfaces, pitting is encountered and a goodly proportion is said to be accountable to precipitation of free sulfur, deposited by gravitation, and which, when entrapped by the necessity of alternating ballasting of the vessel with salt sea water, results in a sulphuric acid action.

The stresses brought to bear on oil tanker vessels, at various times, quite evidently is considerable. Therefore, the structure of those vessels of riveted type when stressed, momentarily, above the limit of proportionality could effect change in the circularity of rivet holes without the rivets actually becoming slack, thus precipitating an initial cause for corrosion as electrolytic action would be set up. The steel rivet, in this instance, would be much more preferable than the softer (iron) rivet.

I desire to extend my thanks with others to the author for his engaging and instructive presentation.

Mr. W. E. Lewis,* Visitor: The author is to be warmly congratulated upon his presentation of an interesting and comprehensive contribution to the recurrent problem of restricting the wastage and pitting that affects hulls of ocean-going ships.

The table of references shows that many such contributions have been made on this important subject, in which have been described the fundamental factors that induce corrosion in hull structures and, also, the measures that should be taken to check their destructive effect. Yet, as the author states, "epidemics of corrosion of the underwater body seem to have occurred in cycles in the marine industry"; to which could be added "and still continue to occur."

This, it is considered, is due largely to shipowners and builders not taking full advantage of existing information and experience, until faced personally with a serious example of pitting and the possible consequence of heavy expenditure for renewals and repairs. As the result of two recent cases of serious corrosion an owner and a builder, separately, decided to descale the shell plating of newly ordered vessels up to the deep load line. It is thus essential that interest be stimulated frequently in the practical measures that, whenever they have been taken, have proved effective in the limitation of hull corrosion. In this respect, the present paper should prove most valuable.

The writer agrees with the author's presentation of the various aspects of the problem and with the conclusions drawn therefrom. The following observations are thus submitted in amplification of some of the statements made, based on the writer's experience.

In view of the evidence presented, both verbally and pictorially, by the author that severe corrosion can result from the presence of semi-disintegrated mill scale beneath a paint-coating, there appears to be no logical argument why such a condition should be perpetuated. Possibly the additional first cost of descaling the underwater shell plates of a new ship would seem an unnecessary burden, but the writer has shown[26] that this extra can be less than the expense involved in a single docking of a ship. If, therefore, descaling can eliminate one docking, it can confer a financial benefit.

* Lloyd's Register of Shipping, Glasgow, Scotland.

The question of effective protection assumes an added importance in these days, due to the progressive increase in the cost of materials and labor. A case has occurred in this country, of a new ship which was so badly corroded during the period of fitting out that approximately £2,500 was spent on renewals and repainting before delivery. The initial cost of pickling the plating to the deep load line would be wetween £1,500 and £1,800. It would appear that, in this instance, pickling would have been advantageous.

The writer supports the author's remarks (pages 43 and 44) in respect of the effect of mill scale in repairs, and considers that new plates, built into older structures, should also be initially descaled.

The development of welded ship construction has produced a new phenonmenon in corrosion effects in that, when internal members are welded to the shell, the heat transmitted through the plating is sufficient to disintegrate partially the mill scale on the immediately opposite outer surface. In many cases deep external pits develop on these localities, as shown in Figure 15, and the writer has seen an all-welded tanker where the bulk of the internal stiffeners were clearly delineated on the outer surface. Descaling is again the only sure measure against such deterioration.

The greatest gain, however, from the initial descaling of shell plates is that the efficiency of the superimposed protective coating is increased considerably.

Experimental evidence has proved that a single coat of paint, when dry, contains numerous pin holes and imperfections, no matter how carefully it may be applied. This applies especially to sprayed paint coatings. As the author says, the period of weathering, nowadays, is too short for complete descaling and nothing is more difficult to remove by scraping and brushing than the patches of mill scale attached to the plating when painting is done. These patches prevent close adherence of the paint to the metallic surface and, during the fitting out period, water can seep through the protective coating and induce galvanic corrosion where scale and metal meet. Further, if electric welding is carried out subsequently afloat, any electrolytic action will take place in this enclosed water, the resultant products, gaseous or solid, pushing up the paint film in the form of blisters.

The rust formed on the surfaces of pickled plates is, however, loose and powdery and can be removed with greater facility. Closer contact between the priming coat and the metallic surface can thus be attained, and the possibility of water being trapped beneath the paint film is correspondingly reduced. In this respect, the author's observations upon the efficiency of washcoat primers are of great interest. It is not the conventional practice, in Britain, to descale a hull on the stocks, and the writer would ask if these paints would be equally efficient if applied to cleaned surfaces of pickled plates under the same circumstances?

The fact that single coats of paint are permeable to sea water necessitates the provision of a multicoat protective covering. In this respect the writer has found[26] that a lesser number of coats have to be applied to descaled plates, in order to attain impermeability, than to plates covered with a partially disintegrated mill scale, and the possibility exists that, with descaled plates, paints that have failed when applied to weathered surfaces may prove satisfactory. As, in his opinion, impermeability is the essential property of a protective coating, this can be obtained more cheaply by descaling the material. To attain this, the writer considers that at least two coats of anti-corrosive paint should be superimposed upon the priming coat.

It may be added that, with an impermeable protective coating, the risk of galvanic corrosion from a copper-bearing anti-fouling paint is reduced to a minimum.

It is generally agreed that the chemical composition or metallurgical constitution plays no part in the rate of corrosion. There is, however, one exception; i.e., the rapid corrosion of the points of rivets made from "rimming" steel. Such rivets caused much trouble in the period between the two Great Wars but, since their use was banned in ships classed with Lloyd's Register, trouble from this source has ceased. Could the author indicate whether such rivets are used at present in ship construction and, if so, has any trouble developed from their use?

The writer concludes with thanks to the author for a most excellent paper.

Mr. A. J. Liebman,* Visitor: Mr. Ffield is to be commended for the very thorough job he has done to express his experience with ship bottom corrosion. This work is based mainly on salt water exposure. Equipment on inland waterways suffers from the same general attacks, especially those vessels that operate in waters with a low pH.

With reference to the last two paragraphs on page 31, it may be in order to state that a thorough blast preparation of rivet heads and weld seams will help greatly to enhance the performance of any marine coating, due to a more uniform stressing of the metal at paint interface, and the more pronounced molecular attraction that can be developed between metal and paint.

Referring to (paragraphs 2, 3, 4, and 5) on page 35, there are paints which will adhere successfully to a mill scale covered surface, thus insulating the assembly. However, launching and operational stresses, as well as impacts, will crack the mill scale before the vessel is fully loaded. The cathodic reaction of the mill scale on the anodic metal will be severe in areas that were damaged during the early stages of service.

* Research Engineer, Dravo Corporation, Pittsburgh, Pa.

Mr. Ffield: The author wishes to take this opportunity of expressing his appreciation to those who contributed discussions to this paper. The response has been most gratifying.

Mr. Arnott points to the superiority of wrought iron over steel in resisting corrosion under service conditions. Even though corrosion tests do not show wrought iron up to advantage, this material may last longer than steel in salt-water service for the following reasons: First, the iron when it corrodes leaves a

very rough stringy surface which forms an excellent base for paint and consequently good paint adhesion generally is obtained; secondly, as pointed out by Newman[17] the mill scale on wrought iron is likely to be less adherent and less damaging than "the hard black oxide scale on steel (which) is very deleterious in its effects and more seriously so than in wrought iron." There may, therefore, be less likelihood of running into mill scale corrosion with wrought iron.

Mr. Arnott's remarks concerning rivet corrosion are pertinent in that he points to the importance of proper driving of the rivet point and avoiding overcalking. The author fully agrees with Mr. Arnott regarding this, particularly his reference to thin fins which tend to break down the paint film at the fin as well as creating localized turbulent areas which will promote corrosion.

Messrs. Arnott and Lewis refer to the susceptibility of rimmed steel rivets to pereferential corrosion attack. The author in collaboration with Mr. F. L. LaQue of The International Nickel Company has made tests to duplicate this form of corrosion. As a matter of interest the rivets shown in Figure 21 are rimmed steel rivets from this test and it will be observed that there is some preferential etching of the segregated core. Table VI shows the results of these tests.

It is interesting to note from this table that there is no difference in the rate of attack on rimmed steel rivets as compared to killed steel rivets when the test is made in pickled plate; i.e., without the cathodic influence of mill scale. However, when the test plates are covered with mill scale, rimmed steel rivets do seem to corrode somewhat faster than their killed counterparts.

The segregated core likely to be present in rimmed steel rivets could conceivably be more susceptible to corrosive attack than would be the unsegregated areas. However, the author has never been quite sold on the poor corrosion properties attributed to rimmed steel rivets. The author has seen numerous instances of remarkable rivet corrosion, the vessel shown in Figure 16 being a typical example. In such instances rimmed steel generally has been suspected as being the delinquent but the author has yet to see a clear-cut case where the use of rimmed steel was the sole cause of the trouble. The author believes it is important to appreciate that large tonnages of rimmed steel plate have been used in shipbuilding and to the best of the author's knowledge there have been no cases of preferential attack on the segregated core exposed at the edges of these plates.

TABLE VI

Comparative Performance of Rimmed Vs. Killed Carbon Steel Rivets in Mild Steel Plate Exposed to Salt Water At Kure Beach, N. C.

	RIMMED CARBON STEEL RIVETS		KILLED CARBON STEEL RIVETS	
	As-rolled Plate	Pickled Plate	As-rolled Plate	Pickled Plate
Overall[a] loss from two ends in 3 yrs. (in in.)	0.095	0.052	0.061	0.055
Estimated loss from one end in 3 yrs. (×0.5)—in in.	0.048	0.026	0.031	0.028
Estimated in. per year attack from one end	0.016	0.009	0.010	0.009

[a] Micrometer measurement between rivet head and point.

To answer Mr. Lewis specifically, rimmed steel rivets have been used extensively in ship construction in America and rivet corrosion has been attributed to the use of this material.

Mr. Meurk raises an interesting point when he states that painting the cathode rather than the anode is contrary to usual ship bottom painting practice. The author used this scheme with some success in the steel salt-water piping used on the destroyer escorts built at the Bethlehem-Hingham Yard during the war. (Reference: "Recommendations for Using Steel Piping in Salt Water Systems," *Journal of the American Society of Naval Engineers*, February, 1945). To avoid galvanic corrosion, steel valves and fittings were specified throughout. However, on the early ships in some instances it was not possible to obtain steel valves and bronze valves had to be substituted. The cathodic area of the bronze valves was reduced by spray coating them on the inside with polyvinyl butyral. Subsequent inspection of the interior of these piping systems showed that the spray coating had been effective in suppressing galvanic attack of the steel in the immediate vicinity of the bronze valves. However, the adhesion of the polyvinyl butyral on the cathodic surface had not been too good. Other sprayed plastics such as Thiokol would probably have had better adhesion and been more effective.

The author does not think that this practice of painting the cathode conflicts altogether with typical ship painting experience. When a vessel is painted the inference is that the sea water is excluded from contact with the hull. This may not always be true with conventional paints which are often permeable and permit the sea water to seep through and make contact with the steel. In fact, the selection of special pigments is often based on their ability to passivate this seeping water and prevent corrosion of the steel underneath. From the foregoing it will be seen that conventional ship painting practice may permit contact between the entire underwater body and the sea thus permitting the establishment of a large anodic area coupled to a comparatively small cathodic area of the propeller.

Mr. Meurk's remarks regarding red lead paints are interesting. There is no general agreement regarding the suitability of these paints for underwater protection. In fact, some are of the opinion that red lead is an unsuitable pigment for continuous exposure to salt water. (Reference: *Journal of the Iron and Steel Institute*, **165**, Part 3, "Performance of Anti-Corrosive Compositions in Sea Water" by J. C. Hudson:) Hudson states that "pitting was found to be more prevalent and more pronounced when the pigment of the anti-corrosive composition contains red lead." Mr. Meurk suggests about six hot summer days as being a suitable drying time for linseed oil base paints. In the author's opinion this is insufficient and in fact two to three months are likely to be required to complete the drying cycle. In the last two years the author has made drydock inspections of four vessels painted with linseed oil red lead (27-pound) paint, each with better than two months drying time, and no tendency toward pitting was noted, in fact the paint protection was above average.

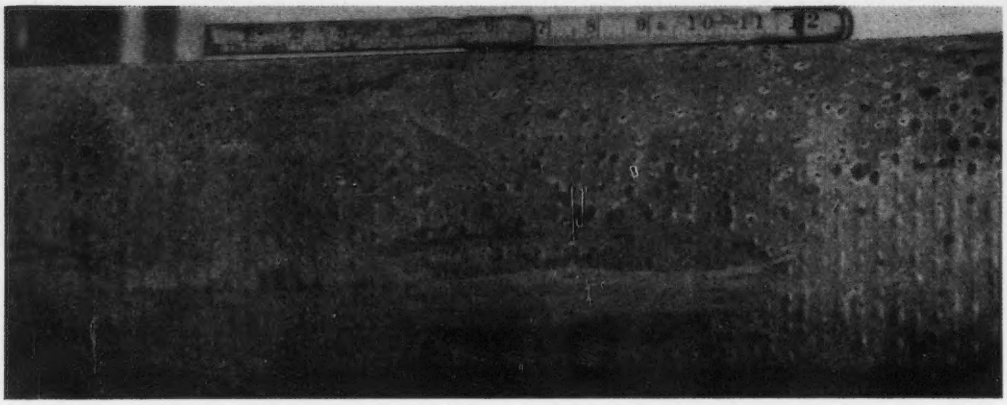

Figure 25—Photograph showing painted propeller shaft of destroyer escort in drydock at the conclusion of its outfitting period of approximately six weeks. Shaft had been painted with two coats of zinc chromate priming paint. Note how blistering has tended to follow machining marks.

Messrs. Meurk, Speller, and others refer to the corrosion of the Great Lakes ore ships during the depression years of 1931-1932-1933. A number of plausible theories have been suggested to explain this interesting corrosion phenomenon. However, none suggests mill scale as the stimulant of the corrosion. It is interesting to note, as Mr. Meurk points out, that a policy of drydocking and sandblasting was adopted subsequently. If mill scale had been the delinquent, this sandblasting would have been effective in eliminating the trouble. In a recent communication from a hull superintendent of a large ore fleet operating on the Great Lakes, the author was advised of instances where large areas of mill scale were present on the underwater body of ore ships after eight or ten years of operation. Even in fresh water these bottoms would be vulnerable to attack if the mill scale was substantially bare of paint or if the paint was such that the water could seep through and reach the steel underneath.

In this connection Mr. Liebman's statement about equipment on inland waterways suffering from galvanic corrosion due to mill scale is important. Contrary to expectations there are some indications that mill scale corrosion in fresh water may be particularly damaging. The total corrosion due to the galvanic effect should be less in fresh water than in sea water. However, because of the poor electrical conductivity of fresh water, it is likely that the corrosion would be more concentrated and confined to the immediate proximity of the mill scale.

The author is glad to receive Mr. Meurk's comments regarding zinc plates. The practice of substituting slabs of soft steel combined with painting the propeller is sound. Even if most of the paint on the propeller eventually is lost, it will be effective in diminishing the damaging ratio of cathode area to that of the anode as long as any paint is remaining.

Captain Chadwick's examples of maintaining a suitable balance between anodic and cathodic areas are interesting and illustate in a striking manner some of the practical aspects of corrosion engineering.

Replying to Mr. Malcolmson, the author has had no first-hand experience with rubber coatings in the vicinity of the propeller aperture. However, several owners are now trying this scheme and reliable information should be forthcoming shortly. Hot spray coatings with self-curing plastic or synthetic rubber appear to be promising in this application. A number of years ago the United States Navy reported success with sheet rubber covered shaft struts and rudders on destroyers where erosion conditions are extremely vigorous. This scheme should be practicable for new construction but generally would not lend itself to drydock application because several days would be needed to complete the job.

The author believes that Mr. Malcolmson is correct in tracing much of the corrosion trouble in way of welding to the velocity effects stemming from the disturbance caused by the weld reenforcements. His plan of adding an extra coat of priming paint to the welds is sound practice. However, in line with Captain Chadwick's discussion, the author has encountered slight corrosion and blistering of paint on the welding of both pickled and sandblasted ships during the outfitting period where no velocity effects would be present. The balance of the paint system was generally in perfect condition. This type of paint failure is due probably to trapped moisture in the weld ripples or, as Captain Chadwick points out, the paint has a tendency to flow away from high spots. An extra coat of priming paint has been effective in suppressing this blistering.

Regarding Mr. Malcolmson's query concerning the source of white deposits, these occur on the cathodic area. In the case of stray current corrosion (as opposed to stray current "protection"—see Figure 8) this generally will be somewhere on shore, since the electric power most likely is generated on shore. In the case of mill scale corrosion the cathode is any area of mill scale which is devoid of paint or on which the paint film is permeable and the deposits will therefore be on the ship—Figure 20, for example.

Mr. Malcolmson feels that welds and riveted joints in plates which had the mill scale previously removed should be sandblasted prior to painting. This is good practice; however, it is not necessary to do this in order to avoid mill scale corrosion because the area

of heat scale on the weld or rivet point is so slight that it is inconsequential. The principal benefit is that weld slag and any loose heat scale are removed from the surface of he weld. Such foreign matter otherwise might become detached and cause a break in the paint film.

Concerning the effect of finishing temperatures on hot rolled plates, the author has made several studies at different times to investigate the practicability of controlling finishing temperatures to insure better weathering or better pickling properties. These studies indicate that the reward is hardly worth the effort on the commercial grade of steel investigated.

Mr. Malcolmson's concluding question is indeed a puzzling one. Frankly, the author does not know why sandblasted steel shows such a tendency toward blistering. Some feel that it is due to the fact that the steel is "raw," others feel that the roughness may be trapping moisture, etc. Since a sandblasted surface is a series of hills and valleys, it may be that premature failure by blistering occurs because of early failure at the "hills" where paint coverage is subnormal. In this connection adhesion is often poor on machined parts or the machined parts show an increased tendency toward blistering. An example of this is shown in Figure 25, where the blistering has followed the hill and valleys caused by the machining marks on a propeller shaft.

Mr. Devoluy highlights an interesting problem when he points to the relatively low impermeability of conventional underwater paints as compared to the effective barrier created by linseed oil red lead paint. As far as the builder is concerned, a paint for the underwater body which is permeable may have some advantage during fitting out. It is often extremely difficult to avoid all electrical leakage from the ship to the shore during this period. With a permeable paint this will not result in much damage because the corrosion will be spread over the entire underwater body and not necessarily concentrated at holidays. With an impermeable paint, however, the corrosion can take place only at holidays in the paint resulting in extremely localized corrosion in the event that there is current leakage from the ship to the shore.

Mr. Devoluy's remarks concerning the performance of vinyl paint systems are in general agreement with our own experience with one or two exceptions. It is not unusual for long streaks of paint to be scraped from the bottom of large tankers during operation and numerous vessels scraped to bare metal have been examined in drydock by the author. In no case has he observed any concentration of corrosion at these areas on vessels which were pickled or sandplasted, irrespective of the type of paint—vinyl, phenolic alkyd or other conventional paint systems. Corrosion was severe, of course, on vessels which had not had the mill scale removed as noted in the paper. Incidentally, the corrosion shown in Figure 2 is an example of this. It was accompanied by general scraping off of the paint for a distance of about 150 feet from the stem.

In the author's opinion the significance of the insulating effect of an impermeable anti-corrosive paint depends on the source of the electric current. For example, if the currents stem from stray weld-currents generated on shore, say during outfitting, then the corrosion with an impermeable paint will be severe at holidays and in the case of the permeable paints the corrosion will be widespread but the depth will be inconsequential. If, on the other hand, the cause is a galvanic current due to mill scale, then the relatively impermeable paint will prevent the access of water to the mill scale and prevent the flow of galvanic currents. Under these latter circumstances there is no question that the impermeable paint is the better type especially if adequate adhesion to the mill scale can be obtained.

The author is in agreement with the remarks of Mr. Place and Captain Rodgers regarding corrosion of hull plating between the L.L.L. and D.L.L. It is likely that much of the trouble encountered in this locality stems from the fact that this area is particularly difficult to protect with paint. Our drydock inspection records show numerous instances of early failure of conventional boottopping and topside paints on new tankers. However, the performance of several brands of vinyl plastic paints or vinyl-alkyd paints has been outstanding in the area between the L.L.L. and rail.

There is plenty of room for improvement in boottopping and topside painting practices and paints. Even though mill scale corrosion is not a problem in this area, removal of the scale will add to the performance of the paint. The author recently had the opportunity of inspecting a tanker, the hull plates of which had been pickled from the keel to the bottom of the shear strake. The shear strake had been wire brushed prior to painting but much of the mill scale was still intact. The inspection showed that there were numerous blisters and local failures where mill scale had become detached on the shear strake whereas the rest of the boottopping paint was in comparatively good condition. On a sister vessel the pickling included the shear strake and the improved paint performance was striking.

The instance referred to by Mr. Place of the new passenger cargo ship built in 1939 where most of the mill scale had weathered off during construction is typical of what might be encountered if stray current corrosion occurred at the outfitting basin. The plating shown in Figure 7 is an example. This vessel was substantially free of mill scale at the time of launching but due to a defective welding circuit between the ship and the shore extensive stray current corrosion occurred in way of scratches and rivet points. The vessel was repainted in drydock and no further corrosion occurred since the stimulating cause (namely, welding currents) was no longer present. Two sister ships built at the same time were unaffected. As pointed out in the paper, the telltale clue is the absence of white deposits on the ship when stray current corrosion takes place on the plates or rivet points.

Mr. Place is correct in emphasizing the importance of proper paint protection. He refers to the use of marking paint as a possible source of trouble. As a general rule these paints adhere well especially when

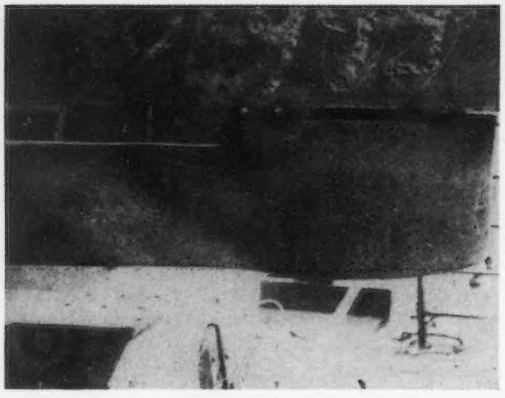

Figure 26—Photograph showing corrosion in way of lettering on tanker rudder. The paint used for lettering was probably incompatible with the marine paint system subsequently applied and thereby caused premature failure of the marine system, where it covered the lettering.

applied to hot plates and there are many instances of these marking paints being intact when the paint film as a whole has fouled. As noted by Mr. Place, this is not always the case as shown in Figure 26.

Mr. Benford draws attention to unplugged overboard discharges and their effect on the adhesion of hull paint. This is a real drydock problem since it is not always practicable to stop all discharges. Some repair yards attempt to overcome this difficulty by installing temporary extensions to the outlet which form a watertight seal and carry the water clear of the hull. Proprietary devices are available for this purpose. About the only other alternate is to take special precautions to insure that all such discharges are dry during the actual repainting operation and during subsequent drying.

Mr. Preiser's remarks regarding the blasting off of mill scale by means of suitable current density and the cathodic protection of ships' bottoms are interesting. It has been the author's experience that to be effective this method of descaling requires high current densities which cannot conveniently be obtained at the fitting out basin. Furthermore, the calcareous deposits, unless thoroughly removed, do not form a good base for subsequent painting.

The author feels that the proposal of Messrs. Preiser and Silverstein for eliminating the underwater paint system and substituting cathodic protection is fundamentally sound. However, there are a number of practical problems associated with this scheme and its application may be limited. At the present time we are protecting one of our steel floating drydocks with this scheme and this should turn out to be a good application of the method since no velocity effects are involved, neither is fouling of the bottom of any consequence.

Captain Ingram's summary of the requirements for an ideal low-cost, anti-corrosive, anti-fouling system is both interesting and practicable. While the author agrees with him that pickling may be presently the cheapest and best method for new work, he cannot agree that it is "just as important to eliminate mill scale in the bilges and tanks of the interior of the hull." Our experience has been that the damaging effect of mill scale is experienced only with continuous immersion. The alternate immersion, as, for example, on the inside of tankers, generally results in a rapid deterioration of the mill scale so that after several months of operation the scale is essentially all removed.

We also agree that sandblasting is an expensive and messy job to do, but present indications are that for repairing failures in plastic paint systems such as the vinyls, it may be necessary to resort to spot sandblasting in order to get satisfactory results. Not only will the sandblasting insure adequate cleanliness of the base metal, but it will feather out the remaining paint and improve the adhesion of the new paint to the old.

Captain Ingram raises a point regarding the effectiveness of a wash primer in protecting the steel during fabrication and erection of the ship. He suggests the use of an after pickling paint for this purpose. The latter type of paint caused us trouble in one of our yards where the hull plating was received in the pickled condition and immediately painted on one side with a zinc chromate paint to standard Navy specifications. Subsequently during construction the owner of this vessel wanted to change his proposed conventional paint system to a vinyl type. However, the vinyl system was incompatible with the alkyd resin zinc chromate paint and we were unable to comply with the request.

Inasmuch as the wash primer seemed to be effective under any paint system we explored the possibility of using these primers as an after pickling paint intended to protect the steel during construction. We found that one coat would offer complete protection for about a month and two coats would offer protection for several months as shown in Table VII. Wash primers may well prove to be a practicable method of protecting steel during fabrication and we are now trying out this system in one of our yards.

The author is in full agreement with Mr. Purdy's comments regarding the corroding conditions likely to occur at storage sites for surplus vessels. The importance of stratification or periodic variation in salinity and dissolved oxygen concentration cannot be over-emphasized.

It would seem that the survey referred to by Mr. Purdy was effective in aiding the selection of suitable sites. The author has had the opportunity to inspect several vessels in drydock after their removal from the laid-up fleet. In most cases the underwater body

TABLE VII

Relative Performances of Conventional Wash Primers Exposed to Salt Atmosphere At Quincy, Mass.

PRODUCT	PERIOD OF TIME IN WEEKS DURING WHICH COMPLETE[a] PROTECTION WAS GIVEN			
	Over Sandblasted Steel		Over Pickled Steel (Navy Process)	
	1 Coat	2 Coats	1 Coat	2 Coats
A	1	8	2	10
B	3	10	1	20
C	6	10	3	10
D	6	20	4	20
E	16	41	10	36
F	7	16	4	16

[a] First sign of rusting. Partial protection was obtained for longer periods.

was in good condition although some particularly bad examples of mill scale corrosion were observed in some instances. The latter condition, of course, would be expected to occur when mill scale is present if the bottom paint has deteriorated irrespective of the location of the site.

The author fully agrees that a valuable contribution would be made if the government department charged with the maintenance of these surplus vessels made a study and reported on the condition of the underwater body of these vessels at the time of their removal from the laid-up fleet. Such a survey, however, would have to include pertinent data regarding the presence of mill scale, type and thickness of paint, etc.

Replying to Captain Rodgers, the Navy hot plastic bottom system seems to be the exception which proves the rule. The author is familiar with the excellent performance of this system which does not include a wash primer. There are other paints which perform well without wash primers—paint *F* in Table III, for example. However, subsequent service tests have shown that the performance of paint *F* on the underwater body is measurably improved by the addition of a wash primer. One is tempted to ask Captain Rodgers if the Navy has tried their hot plastic system over a wash primer paint.

Mr. Larrabee's remarks regarding calcareous deposits and the mechanism of mill scale removal are well stated and the author appreciates his clear-cut distinctions.

Dr. May's clarifying remarks regarding the polarity of anodic and cathodic areas are appreciated, as are his observations on the potential difference between copper and steel, and mill scale and steel, in flowing sea water. However, in the author's opinion the magnitude of the potential difference between mill scale and steel is of secondary importance to the fact that mill scale is likely to be present in such relatively large areas. As brought out in Table II the depth of corrosion is directly proportional to the area of mill scale present as compared to that of bare steel.

Dr. May's remarks concerning "zincs" are timely. Owners are having to consider substitutions for zinc protective plates because of the current scarcity of this material. As Dr. May clearly points out, substituting low purity zinc for high purity zinc would be of no value.

Dr. May, Mr. Malcolmson, and Mr. Hastie refer to magnesium anodes. The author has had some experience recently with these anodes but they introduce a special problem in that they have to be about 4 inches thick in order to survive the exposure period between dockings. This relatively large thickness may necessitate the installation of special fairwaters to avoid turbulence. Mr. Malcolmson questions the painting of these anodes—zincs or other protective slabs, including magnesium anodes, should not be painted.

The author is in agreement with Mr. Bennett when he states that owners do not always take proper care of the underwater surface of their ships. The importance of a carefully planned procedure for bottom protection cannot be overemphasized. It is also gratifying to learn that it is the practice of many British yards to remove the mill scale from all shell plates by pickling.

Mr. Hastie's remarks concerning the difficulty of painting the keel strake are pertinent. In the author's opinion a practical way to protect this strake might be to make it from a low alloy steel which would be slightly cathodic to the ship's hull. In this way reliance need not be placed on proper painting but the hull as a whole should protect the keel cathodically

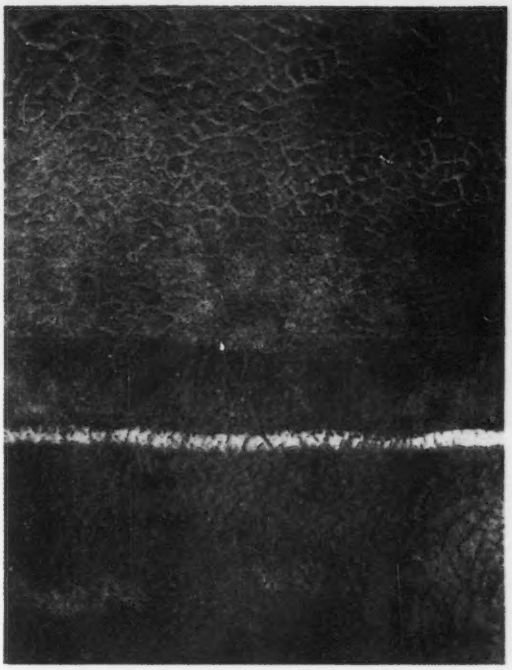

Figure 27—Photographs showing severe corrosion of underlying plate when anti-fouling paint was applied over a paint system which had previously developed checking. Top, paint system as docked. Bottom, after sandblasting, showing corrosion in plate—corrosion depth 1/16 to 3/16-inch.

TABLE VIII

Relative Performance of Five Brands of Wash Primers Over Sandblasted and Pickled[a] Steel Under Three Brands of Conventional Anti-Fouling Paint.[b]

Paint System[c]	Wash Primer[c]	TIME TO FAILURE IN WEEKS			
		Sandblasted Panels		Pickled Panels	
		With No. Wash Primer	With Wash Primer	With No Wash Primer	With Wash Primer
A.....	a	10	71	14	71
A.....	b	12	44	19	44
A.....	c	10	71	17	71
A.....	d	10	36	17	36
A.....	e	10	71	14	71
B.....	a	17	40	19	40
B.....	b	17	71	28	71
B.....	c	17	71	28	71
B.....	d	19	59	28	71
B.....	e	19	71	23	71
C.....	a	28	71	28	71
C.....	b	32	71	40	71
C.....	c	32	59	48	49
C.....	d	28	71	40	71
C.....	e	28	71	32	71

[a] Navy pickling procedure including immersion in 5 per cent by volume sulphuric acid at 170 degrees F followed by a water rinse at 170 degrees F and a final dip in a bath at 200 degrees F containing approximately ½ percent by weight sodium dichromate and ½ per cent weight phosphoric acid.
[b] Four-coat systems including two coats of conventional primer, one coat anti-corrosive and one coat anti-fouling.
[c] Letters indicate brand.

wherever it is devoid of paint. As far as the author knows this practice has not been tried, but it looks as though it is worth investigating.

The author agrees with Mr. Liebman that there are some paints which will adhere successfully to mill scale, for example, paints *F* and *G*, Table III. However, as pointed out in the paper, when large areas of mill scale are buried beneath paint the vessel is always vulnerable to attack unless the owner follows a carefully planned schedule of frequent dockings. If this routine is upset, mill scale corrosion is likely to occur if the paint film deteriorates sufficiently. An example of this delayed attack is shown in Figure 19.

The author agrees with Mr. Lewis that the extra cost of descaling a vessel may well be less than that represented by a single docking. Actually it is hard to evaluate the benefits which accrue from descaling. For example, the peace of mind and assurance from freedom of severe galvanic corrosion stemming from mill scale should be worth the additional cost. However, apart from this the shipbuilder may find that the plate cleaning costs prior to painting are reduced when the hull is made from pickled plates. Also welding is easier, but this is hard to measure—welding speeds may increase anywhere from 1 percent to 5 percent depending on how clean or dirty the plate is initially. Apart from this there is less tendency toward undercutting at the edge of the weld when the plate is free from mill scale and consequently there should be less "clean up" rewelding of undercut edges, etc.

In the paper the author referred to wash primers only because their use is so important after sandblasting. However, the author's experience is that these paints are just as effective on pickled plate as on sandblasted. This is shown in Table VIII.

The author fully agrees with the remarks of Mr. Lewis and Captain Ingram regarding adequate undercoating. This is borne out in the photograph (Figure 27) which shows what can happen when anti-fouling paint comes into intimate contact with the plate.

President Woodward: The keen interest which Mr. Ffield's paper has brought out is an indication of its value. It is fine to have practical papers of this kind presented. They are very helpful, they encourage discussion, and they constitute a very useful contribution to the *Transactions* of the Society.

I wish to thank Mr. Ffield and those who have taken the time to present discussions as they have done, because it means they have taken the time to read his paper carefully.

Topic of the Month

Silicone Paint Protects High Temperature Refinery Equipment

*By MAX LEAVENWORTH**

A FEW YEARS ago, maintenance men in a Southern refinery found it almost impossible to protect a certain heat treater stack from the corrosive atmospheres and surface temperatures ranging constantly from 400° to 800° F. All the best organic heat-resistant coatings were applied but none lasted more than a few days.

Then a new type of semi-organic paint, formulated with silicone resin, was applied. Although identical in application and appearance to previously used paints, this finish retained its original appearance far longer. In spite of the high temperatures and corrosion-laden atmosphere, the stack did not need painting again for over two years.

That kind of protection is typical of the extreme-temperature service provided by silicone-based paints. Stability is inherent in the silicone molecule itself. The backbone of the molecule is its silicon-to-oxygen linkage, similar to that found in sand, glass and quartz. This chain linkage is half again as strong as the carbon-to-carbon link common to organic materials. As a result, silicones retain their characteristics in spite of extreme temperatures, weathering, oxidation, ultra-violet light and other destructive influences. Silicone binding vehicles therefore maintain film integrity much longer than conventional binders under similar conditions.

*Manager, Dallas Branch Office, Dow Corning Corp.

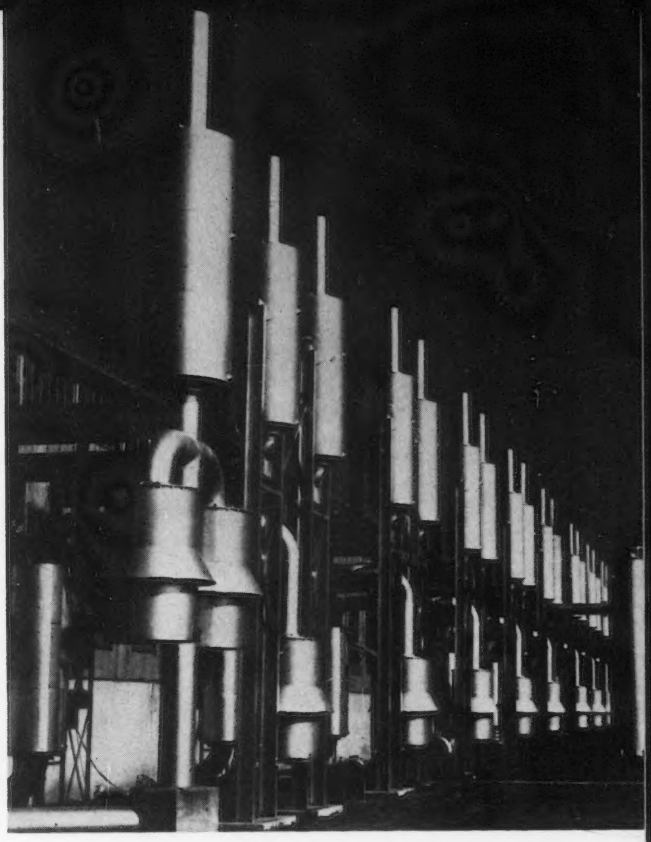

Figure 1—Two coats of aluminum paint based on a silicone vehicle withstood surface temperatures of 400° to 600°F on these gas compressor exhaust mufflers over three years. Previously used organic paints lasted up to 30 days. (Photos Tennessee Gas Transmission Co. and Kansas Paint & Color Co.)

Pigments Are Stable

An important factor in the formulation of silicone paints is the heat stability and relative inactivity of available pigments. Finishes pigmented with aluminum powders, zinc dust, flaked stainless steel or powdered mica may be expected to maintain stability at temperatures ranging up to 1000° F. Black, white and colored pigments are generally limited to applications below 700° F.

Certain precautions must be observed in applying silicone finishes. The surface to be painted must be absolutely clean and dry. If corrosive conditions are excessive, a primer coat should be used. Paint may be applied by either brush or spray. One coat is often sufficient but best results are obtained with two.

In spray application, the first coat need only become air-dry before the second coat is applied. In brush application, the first coat must be cured for the equivalent of 30 minutes at 500° F, or enough to prevent lifting when the second coat is applied, but not so much as to prevent second coat from wetting.

Curing Often Is Simple

The last coat should be allowed to air-dry at room temperature for 30 minutes to an hour and then cured for the equivalent of about an hour at 500° F. Curing schedules, of course, depend largely upon the conditions surrounding the application. In most refinery applications, curing is accomplished simply by putting the painted unit back into operation.

Although silicone finishes already possess properties unmatched by other finishes, properties which have made them particularly useful in the petroleum processing industry, every effort is being made by various laboratory groups toward improving them still further.

Some progress has been made on the formulation of modified silicone finishes and on silicone-alkyd copolymers. Priced much lower than straight silicone-based formulations, they are for the most part faster curing, more thermosetting and show somewhat greater adhesion to steel. However, the straight silicone paints are still markedly superior in heat, oxidation and corrosion resistance.

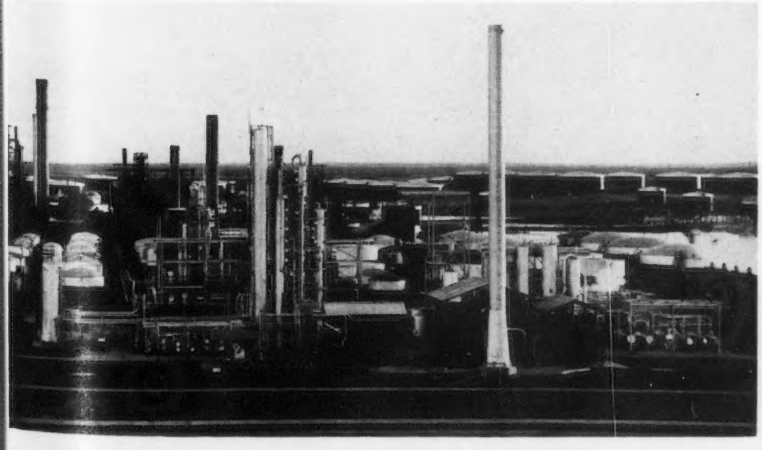

Figure 2—Two coats of silicone-aluminum paint applied to this solvent plant processing stack withstood temperatures from 400° to 800° F for 40 months, compared to less than three months service from best organic paints. (Photos Continental Oil Co. and Kansas Paint & Color Co.)

NACE News

North East Region Names New Officers

New officers have been elected by North East Region as follows: T. P. May, The International Nickel Co., Inc., New York, chairman; George E. Best, Mutual Chemical Co., of America, Baltimore, vice-chairman and H. W. Dieck, Long Island Lighting Co., Mineola, N. Y., secretary-treasurer.

Metropolitan Section Officers Are Elected

The following new officers have been elected by Metropolitan New York Section: Kempton H. Roll, Lead Industries Association, chairman; George C. Hull, Jr., Anglo-American Varnish Co., vice-chairman; F. J. LeFebvre, Electro Rust-Proofing Corp., reelected secretary-treasurer.

A talk illustrated with colored slides on the topic "Surface Corrosion Prevention Used by the U. S. Corps of Engineers," by Raymond E. Michalek, Office of Chief of Engineers, Corps of Engineers, Washington, D. C. was given to Metropolitan New York Section December 11. There were present 61 members and guests.

Mr. Michalek covered application of vinyl, alkyd, phenolic, linseed oil, aluminum and red lead paints as well as coal tar enamels.

A slide film "Combating Corrosion With the Metal From the Sea," showing the economic advantages of protecting buried metal with magnesium was also given.

Pittsburgh Section Meets

E. H. Dix of the Aluminum Company of America research laboratory, New Kensington, Pa., addressed members of Pittsburgh Section January 3 at Mellon Institute. His topic was "Stress Corrosion from the Metallurgical Viewpoint."

Baltimore Section Selects 1952 Officers

New officers elected December 13 for Baltimore Section are George E. Best, Mutual Chemical Company, chairman; L. G. Von Lossberg, c/o Sheppard T. Powell, vice-chairman; A. L. Alexander, Naval Research Laboratory, secretary-treasurer.

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The annual index to technical material published in Corrosion, appearing in the December issue, consists of a topical cross-referenced tabular index with author index and a tabular topical index to corrosion abstracts.

NACE MEETINGS CALENDAR

February

7—Pittsburgh Section. Corrosion Problems in Industry, speaker to be announced.

8—Philadelphia Section. Poor Richard Club, Philadelphia.

12—Houston Section. Joint meeting with University of Houston Junior Section. Program: Color sound motion picture, "Elementary Corrosion," supplied by Allegheny-Ludlum Steel Co. Second part of the program will be a talk by a University section student on a pipe line subject.

19—Chicago Section. Cathodic Protection and Common Sense by D. C. Glass, Pure Oil Company.

27—Sabine-Neches Section. Meeting at Lake Charles. Refinery Painting, by W. B. Cook, Gulf Oil Corp.

March

6—Pittsburgh Section. Bacteriological corrosion, speaker to be announced.

13—Detroit Section. Engineering Societies' Rockham Bldg., Detroit.

18—Houston Section. A. P. Farr, Hughes Tool Co., Houston, "Fatigue Corrosion in Drill Stems." Also Stanley C. Moore, Drill Collar Service Co., Midland, Texas, "Reducing the Corrosion Factor in Drill Stem Failures by Application of Cathodic Protection." A discussion from the floor by Oliver Osborn of Dow Chemical Co., Freeport, will follow.

18—Chicago Section. F. W. Pfohl of Armour Research Foundation, tentatively scheduled to speak on "The Mechanism of Corrosion Inhibition by Polar Organic Compounds."

25—Southwestern Ohio. Galvanic Corrosion and Related Materials, by Raymond B. Hoxeng, United States Steel Co. laboratory.

27—Sabine-Neches Section. At Port Arthur, Texas. Panel discussion. Lewis M. Nieliwocki, chairman.

Merits of Australian Coating Are Described To St. Louis Section

Merits of an inorganic coating "Dimetcote," developed by the Dimet Ptg. Co., Ltd., Melbourne, Australia were explained to Greater St. Louis Section December 17. E. Ghent Johannes of Mineral Products Company gave the six important properties of the material as: 1) Completely inorganic, 2) One-coat protection, 3) Provides cathodic protection, 4) High adhesion properties to steel, 5) Excellent abrasion resistance, 6) Proved protection on several million square feet from one to ten years.

Colored slides were shown of various kinds of installations protected by the material.

Three motion pictures followed the talk: Flotation Painting of Water-Sealed Gas Holders, Consolidated Edison Co. of New York. Comments on this were made by E. F. Trunk, Laclede Gas Co., St. Louis; The second motion picture was Solving Corrosion Problems, by Lukens Steel Co., Coatesville, Pa. and the third Neoprene, Versatile Chemical Rubber, by DuPont Company, Wilmington, Del.

Because of adverse weather only sixteen were present.

Next scheduled dinner meeting January 21 features a talk "Neoprene and Other Elastomers as Corrosion Resistant Membranes," by L. S. Bake, Rubber Laboratory, DuPont Company, Wilmington, Del.

W. J. Ries, Tretolite Company, has been named vice-chairman succeeding W. F. Gross, who has left the St. Louis area for a position with Narmco, Inc. San Diego, Cal. Mr. Ries also is program chairman for the section.

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Pages in the Corrosion Abstract Section of Corrosion are numbered serially in each volume so they may be bound by years with the annual index.

NACE POLICY ON DUES IN ARREARS

No member of the association with dues in arrears for three months shall receive publications of the association until such dues are paid. Members in arrears one year shall be dropped automatically from membership.

If your dues are not received at Central Office by the latter part of March, you will be dropped from the list to receive NACE publications and mail. Accordingly the March issue of CORROSION will be the last received by those so dropped.

In order to avoid interrupted mail and missed copies of CORROSION members are urged to remit dues before the deadline. Much work will be eliminated at Central Office if members remit before the date stipulated.

Talk and Discussion On Ice Melting Salts Scheduled at New York

A talk and discussion on corrosion by ice melting salt is the scheduled feature at the February 6 meeting of Metropolitan New York Section at Building Trades Employers' Association, 2 Park Ave., N. Y. Charles T. Roland of Calgon, Inc., Pittsburgh, Pa. will talk on "The Corrosion Effects and Inhibition of Street De-Icing Salt."

Frank E. Kulman of Consolidated Edison Company and chairman of TP-19 on Corrosion by De-Icing Salts will moderate a discussion. Mr. Roland's talk will cover the joint investigation of de-icing salt made by Calgon, the Department of Sanitation of the City of New York and the New York Consolidated Edison Company. Discussions are to be made by Richard Fenton of the New York Department of Sanitation and Victor Veit of Consolidated Edison Co.

A short motion picture "A Winter Wonder" which depicts operation of snow melting systems will be shown also.

Process Equipment Welding and Mild Steels Are Discussed

Scheduled for the February 4 meeting of Eastern Wisconsin Section is "Factors Influencing Corrosion of Mild Steel and Mild Steel Welds in Process Equipment," by R. A. Huseby and M. A. Scheil.

Eighty persons were present at the January 8 meeting to hear F. L. LaQue of The International Nickel Co., Inc., New York speak on corrosion testing. The meeting was a joint gathering of the NACE Section and Milwaukee Chapter of the ASME.

Corrosion Tour Was North Texas' Topic

A discussion on the recent Permian Basin Corrosion Tour was presented to 32 members and 24 guests of North Texas Section January 7. J. C. Spalding, Jr. of Sun Oil Company was the speaker. H. R. Adair, purchasing agent of Sun Oil Company, Dallas, also gave a short talk titled "The Purchasing Agent versus the Engineers."

Western Region Elects Officers for 1952

New offices of Western Region assumed their duties at the January 16 meeting at Rodger Young Auditorium, Los Angeles. New officers are W. M. Schilling, Southern Counties Gas Co., chairman; E. H. Grizzard, Signal Oil & Gas Co., vice-chairman; Miss Flora Lombardo, Amercoat Corp., secretary-treasurer.

L. L. Whiteneck, Long Beach Board of Harbor Commissioners, was named director to take office following the 1952 conference at Galveston.

Correlating Committee Report Being Reprinted

A second printing of 2000 copies has been ordered of the Report of the Correlating Committee on Cathodic Protection published in October 1951 by the National Association of Corrosion Engineers. Concurrently, a new schedule of prices for multiple copies of the second printing has been established as follows:

1 to 10 copies, each.....50c
11 to 100 copies, each.....35c
More than 100 copies, each.....25c

Demand for copies of the publication has been good and there is every reason to believe it will continue to be popular for several years to come.

Range Succeeds Swanson

E. C. Range of The Okonite Company, Atlanta, Ga. has been named to succeed A. R. Swanson as director for South East Region NACE on the board of directors. His term will expire in 1954.

Magazines Received

The September issue of Revisto Do Clube de Engenharia, a publication of Engenharia Editora S. A., Av. Rio Brancho 124-26, Rio de Janeiro, Brazil has been received at Central Office NACE.

The association also has been put on the mailing list of United Gas Association's "United Gas Log."

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Tentative Schedule of Washington University Short Course Is Given

A tentative schedule for the Washington University (St. Louis, Mo.) Corrosion Short Course has been completed. All ten of the listed lecturers are NACE members. F. L. Whitney, Jr., North Central Region NACE Director has worked closely with university officials in arranging details of the course and the degree of participation by the association.

The course is scheduled to be held September 8-12, inclusive, with enrollment scheduled to begin during July. Limits on the number which may be accommodated have not been announced.

The scheme for the course provides for a lecture, followed by a discussion period. Lectures and discussions will be held daily 9 to 12 am and 2 to 5 pm.

The tentative schedule is as follows:

Monday, September 8

9-12 am Corrosion Reactions, Factors and Fundamental Mechanisms. Dr. H. H. Uhlig, in charge of Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge.

2-5 pm Treatment of the Environment—Chemical Methods, Selection and Behavior. Norman Hackerman, Department of Chemistry, University of Texas, Austin.

Tuesday, September 9

9-12 am Guides to Proper Selection of Materials of Construction for Particular Environments. W. Z. Friend, Assistant in Charge, Corrosion Engineering Section, The International Nickel Co., Inc., New York.

2-5 pm Types of Corrosion—Diagnosis and Treatment of Corrosion Difficulties. M. G. Fontana, Chairman, Department of Metallurgy, The Ohio State University, Columbus.

Wednesday, September 10

9-12 am Corrosion Testing Procedures and Evaluation—Factors to Be Considered in Laboratory and Field Studies. F. L. LaQue, in Charge Corrosion Engineering Section, The International Nickel Co., Inc., New York.

2-5 pm Designing to Prevent Corrosion—Basic Principles and Standards for Equipment Design, Installation and Maintenance. R. B. Mears, Manager Research and Development Laboratory, United States Steel Co., Pittsburgh, Pa.

Thursday, September 11

9-12 am Cathodic Protection—Theory and Measurement. J. M. Pearson, Director Research and Development Dept., Sun Oil Co., Newton Square, Pa.

2-5 pm Cathodic Protection—Practical Application and Economics. A. W. Peabody, Electrical Engineer, Ebasco Services, Inc., New York.

Friday, September 12

9-12 am Protective Coatings (Metal and Organic)—Fundamentals and Selection. K. G. Compton, Bell Telephone Laboratories, Murray Hill, N. J.

2-5 pm Protective Coatings—Surface Preparation, Application and Behavior. A. J. Liebman, Research Engineer, Dravo Corp., Pittsburgh, Pa.

BINDERY SERVICE

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These prices cover full cloth, hard cover, sewed volume with the name *"Corrosion"* and the Volume Number and Year stamped in gold on the back. All prices are net to the binder, transportation extra.

Transactions are between the individual and the binder and NACE will not be a party to nor does it offer any warranty of any nature in connection with any transaction. All correspondence should be with the binder directly and all billing will be direct to the purchaser from the binder.

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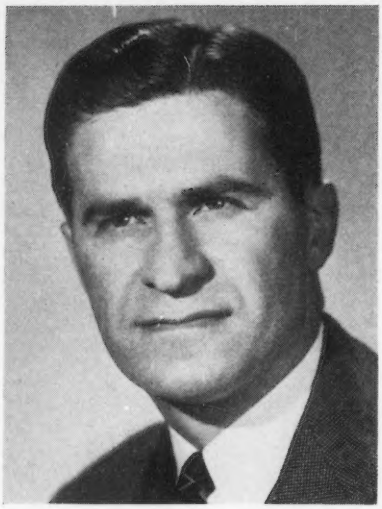
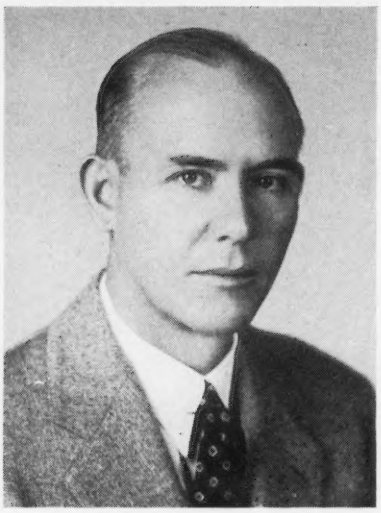
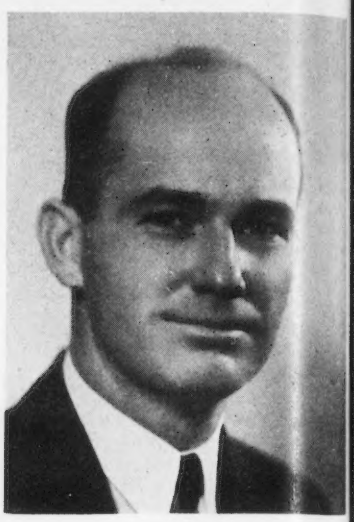
New Officers of Association Are Named for 1952



M. G. FONTANA
President, Ohio State University, Columbus, Ohio.



WALTER F. ROGERS
Vice-President, Gulf Oil Corp., Houston



R. A. BRANNON
Treasurer, Humble Pipe Line Co., Houston.

Tellers who canvassed the mail ballots from members of the association at Central Offices January 7 reported the following elected officers of NACE for 1952:

President—M. G. Fontana, Ohio State University, Columbus, Ohio.

Vice-President—Walter F. Rogers, Gulf Oil Corp., Houston.

Treasurer—Russell A. Brannon, Humble Pipe Line Co., Houston.

Also reported elected were the following:

For directors representing corporate members, H. P. Godard, Aluminium Laboratories, Ltd., Kingston, Ontario and V. V. Kendall, National Tube Company, Pittsburgh, Pa.

For directors representing active members, Norman Hackerman, University of Texas, Austin.

Tellers were named by President N. E. Berry in accordance with the articles of organization to canvass the ballots of November 5, 1951.

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NACE

New Members and Changes of Address

• This list is published principally for use by NACE Regional and Sectional officers in keeping their mailing lists up to date.

NEW MEMBERS

(Additions and Changes Through December 27, 1951)

ALABAMA

GIBSON, SIDNEY A., Tennessee Coal Iron & RR Co. Llec. Lab., Sheet Mill, Fairfield, Alabama.

ARKANSAS

KARLSKIND, DON B., Fesco, Inc., Engineers, 320-322 West Ninth, Little Rock, Arkansas.

CALIFORNIA

GOEN, PAUL S., Dekoron Tubing & Zincilate, 1341 South Hope, Los Angeles 15, California.
MILLAR, MAURY, Industrial Sales Div., Pabco Products, Inc., 475 Brannan Street, San Francisco 19, California.
O'CONNOR, LEO, The O'Connor Rust-Proofing Co., P. O. Box 775, Station H., Los Angeles 44, California.
PARKER, LEONARD S., Pabco Products, Inc., 475 Brannan Street, San Francisco 19, California.
PORTER, CLELL O., Pacific Pipeline Construction Co., 1632 South Greenwood Ave., Montebello, California.
WEIR, JR., C. J., Union Oil Company of California, San Luis Obispo, California.

COLORADO

HARTKEMEIER, LEONARD W., Colorado School of Mines, Department of Chemistry, Golden, Colorado.
MAXWELL, EUGENE C., Barrett Div., Allied Chem. & Dye Corporation, 1220 So. Fillmore Street, Denver, Colorado.

DELAWARE

BUSH, JR., FREDERICK J., Knapp Mills, Inc., Foot of West Street, Wilmington 15, Delaware.
LEONARD, ROBERT E., Knapp Mills, Inc., Foot of West Street, Wilmington 15, Delaware.

GEORGIA

PUTNAM, J. FRANK, Anti-Corrosion Manuf. Co., 2464 Memorial Drive, S. E., Atlanta, Georgia.
STEELE, C. JAY, Anti-Corrosion Manuf. Company, 2464 Memorial Drive, S. E., Atlanta, Georgia.

ILLINOIS

MORRIS, JAMES F., Bauer & Black, 2500 S. Dearborn, Chicago, Illinois.
SANDBERT, PAUL A., Brightly Galvanized Products Co., 3330 So. Cicero Ave., Cicero 1, Illinois.

INDIANA

LUICHINGER, MARTIN J., Indiana Bell Telephone Co., 240 North Meridian, Indianapolis, Indiana.

LOUISIANA

CHRONISTER, JAMES L., Baker Oil Tools, Inc., P. O. Box 148, Scott, Louisiana.
COFFER, HAROLD R., Shell Oil Company, Box 271, Donaldsonville, Louisiana.
HELMS, ROBERT F., 130 Memory Lane, Lafayette, Louisiana.
IRISH, LYNTON B., 3648 Huston, Shreveport, Louisiana.
IRVIN, JAMES A., Arkansas-Louisiana Gas Company, Gen'l Eng. Dept., Box 1734, Shreveport, Louisiana.
JAY, WEBB, Sohio Petroleum Co., Lafayette, Louisiana.
JONES, GASTON V., Arkansas Natural Gas Corp., P. O. Box 1734, Shreveport 4, Louisiana.
KIZER, CURTIS A., Otis Pressure Control, Inc., Box 242, New Iberia, Louisiana.
LOVE, JAMES L., City of Lafayette, Louisiana, c/o Utilities Water System, Lafayette, Louisiana.
MARTIN, HARRY C., Brown Paper Mill Co., Inc., P. O. Box 1472, Monroe, Lauisiana.
MONTGOMERY, WAYNE C., Aluminum Co. of America, 627 Whitney Bldg., New Orleans 12, Louisiana.
MORCOM, ROBERT S., National Aluminate Corporation of Chicago, 108 W. Lawrence, New Iberia, Louisiana.

(Continued on Page 8)

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(Continued from Page 7)

PERKINS, ROBERT L., Macco Sales & Service, Route 2, Box 403-C, Lafayette, Louisiana.
RICHEY, VERNON T., Macco Sales & Service, Route 2, Box 403-C, Lafayette, Louisiana.
RODGERS, JAMES W., Dowell, Inc., Box 830, Lafayette, Louisiana.
WRIGHT, L. LAVELL, Pan-Am Southern Corporation, 1040 St. Charles Avenue, New Orleans, Louisiana.

MARYLAND

HUBARD, STEPHEN S., Davison Chemical Corporation, Baltimore 3, Maryland.

MASSACHUSETTS

BROWN, CHARLES G., United Carr Fastener Corp., 31 Ames, Cambridge, Massachusetts.
MEADOR, RAYMOND B., New England Tel. & Tel. Co., 185 Franklin St., Rm. 403, Boston 7, Massachusetts.
ROBERTSON, OLIVER W., Butler Engineering Co. of N. E., 94 Vernon, Somerville, Massachusetts.
TYTELL, BORIS H., 14 Greendale Road, Mattapa, Massachusetts.

MINNESOTA

EFRON, AARON, The Toni Co., Div. of Gillette Safety Razor Co., 332 Rosabel, St. Paul 1, Minnesota.

NEW JERSEY

ANDERSON, WALLACE M., Devoe & Raynolds Co., Inc., Rutherford & Delancey Sts., Newark 5, New Jersey.
HILEY, R. B., Beach Air Brush Company, Corner Second & Warren, Harrison, New Jersey.
TORRANS, DAVID J., Hercules Powder Co., Parlin, New Jersey.

NEW YORK

BRINSON, EDWIN C., Rochester Products Div., GMC, 1000 Lexington Ave., Rochester 3, New York.
BROWN, CHARLES, 1238 Simpson Street, New York 59, New York.
HOEVELER, JR., J. H., Schuleter-Hoeveler Assoc., Inc., 90 Broad Street, New York New York.
EWING, JAMES H., Knapp Mills, Inc., 23-15 Borden Ave., Long Island City 1, New York.
FULLER, NELSON M., 9 Montclair Ave., Batavia, New York.
JAMES, HARRY C., Hooker Electrochemical Company, Buffalo Ave. & 47th St., Niagara Falls, New York.
KNAPP, ALFRED P., President Knapp Mills Inc., 23-15 Borden Ave., Long Island City New York.
LIMATA, ALBERT J., 200 East 63rd St., New York 21, New York.
PRINE, WALTER H., International Nickel Company, 67 Wall St., New York 5, New York.
SCHLUETER, AUGUST, Schlueter-Hoeveler Assoc., Inc., 90 Broad Street, New York New York.
TSCHUDI, TRAUGOTT, Knapp Mills, Inc., 23-15 Borden Avenue, Long Island City New York.

NORTH CAROLINA

CHAMBERLAIN, JR., FRANK H., Southern Specialties Corporation, 202 Coddington Bldg., Charlotte, North Carolina.

OHIO

BERINGER, WILLIAM J., Aqua-Therm, Inc., P. O. Box 925, Dayton 1, Ohio.
CHENOWETH, WILLIAM F., National Cash Register Co., Main & K Streets, Dayton Ohio.
PANTALONE, JOSEPH A., Chase Brass & Copper Co., Inc., 1121 E. 260, Cleveland 1 Ohio.
SCHOFIELD, CECIL, Republic Steel Corporation, 6100 Truscon, Cleveland, Ohio.
SCHWALM, LAWRENCE H., Ohio Bell Telephone Co., 820 Superior Ave., N. W., Cleveland 13, Ohio.
WOOD, R. L., 323 Plum Street, Cincinnati Ohio.

OKLAHOMA

SCHICK, JR., WILLIAM F., Johns-Manville Sales Corporation, 1701 E. 7th, Tulsa, Oklahoma.
STEFFENS, MARTIN L., Oklahoma Natural Gas Co., P. O. Box 1620, Oklahoma City, Oklahoma.

PENNSYLVANIA

GILBERT, JR., HARRY E., Pittsburgh Plate Glass Company, 125 Colfax St., Springdale, Pennsylvania.
HARRIS, LESTER K., 1120 Highland Avenue, Bethlehem, Pennsylvania.
LAMBERT, WILLIAM R., Texas Eastern Trans. Corp., P. O. Box 431, Waynesburg, Pennsylvania.
LANPHIER, BASIL T., The Carpenter Steel Company, 101 West Bern St., Reading, Pennsylvania.
LUTTRELL, WILLIAM T., Texas Eastern Transmission Corp., P. O. Box 32, Downingtown, Pennsylvania.
McCLINTOCK, OLIVER, 23 Linden Place, Sewickley, Pennsylvania.

TEXAS

BROWN, CHARLES W., W. H. & L. D. Betts, 4615 Holt Street, Bellaire, Texas.
BUTLER, GEORGE D., Corn Products Company, Shell Road, Corpus Christi, Texas.
CHARTRAND, V. EDWARD, 2203 B., Fort Worth Avenue, Dallas, Texas.
EDGAR, LENVILLE C., Tube-Kote, Inc., 2520 Holmes Road, Houston, Texas.
HOLLAND, JR., CHARLES J., Sun Oil Company, P. O. Box 2880, Dallas, Texas.
KIRSTEN, K. W., Texas Eng. & Mfg. Co., Inc., P. O. Box 6191, Dallas 2, Texas.
McGARY, S. U., Midwest Pipeline Service Company, 3854 Arbor, Houston 4, Texas.
MOSIER, BENJAMIN, Convair, Eng. Test Lab., Chemical Section, Fort Worth, Texas.
MUEHLHAUSE, EDWIN H., Lone Star Gas Company, 1915 Wood Street, Dallas, Texas.
PITMAN, HAL J., Southern Union Gas Company, 426 Fifth, Port Arthur, Texas.
SCOTT, PAUL T., Convair, Eng. Test Lab., Chemical Section, Fort Worth, Texas.
SULLIVAN, JEAN H., The Atlantic Refining Company, P. O. Box 2819, Dallas, Texas.
WITT, J. LESLIE, Emsco Derrick & Equipment Co., P. O. Box 1289, Houston, Texas.

UTAH

DISANTO, BARTEL J., Chief Engineer, American Smelting & Refining Co., 617 Pacific Nat. Life Bldg., Salt Lake City, Utah.

WEST VIRGINIA

STOBBS, HENRY A., Wheeling Steel Corporation, Room 418, Wheeling, West Virginia.

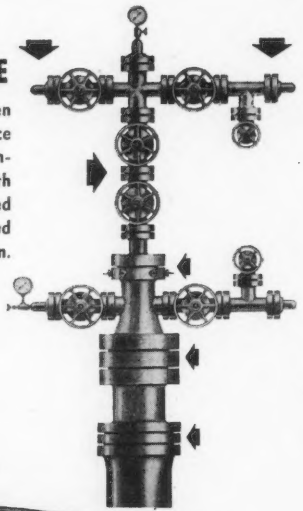
WISCONSIN

ELLIOTT, WM. E., Water Cond. Lab., Allis-Chalmers Manufacturing Co., P. O. Box 512, Milwaukee 1, Wisconsin.
NELSON, FORREST W., A. O. Smith Corporation, 3533 N. 27th, Milwaukee, Wisconsin.
SCHROEDER, CLARENCE E., Mohns Bros. Company, 1751 N. 3rd St., Milwaukee 12, Wisconsin.

(Continued on Page 9)

CORROSION STRIKES HERE

Corrosion in the ring is certain to result when dissimilar metals are flanged up in the presence of a low resistance liquid or electrolyte. Machining of cloth-reinforced plastics exposes the cloth to liquids which hasten deterioration. Forged steel ring gaskets cannot stop this corrosion and alloys frequently increase the rate of corrosion. But it *can* be eliminated!



STOP CORROSION WITH

PESCO

PLASTIC RING SEAL GASKETS

PESCO Gaskets are *molded* of Fiberglas and a special resin, and provide *positive protection* against the flow of electric current between dissimilar metals in a joint. They are form fitting under pressure, have high mechanical strength, and are unaffected chemically by any of the gases or fluids encountered in oil and natural gas production or transmission. When used with insulated sleeves and washers around the bolts, PESCO Gaskets will electrically insulate any joint, and will eliminate corrosion caused by galvanic, long line or stray electric currents. Thousands in service on high pressure christmas trees over the past five years. Widely used to insulate well structures against currents flowing from pipe line systems. Investigate PESCO Plastic Ring Seal Gaskets today . . . sizes available to replace metal rings built to API specification 5-G-3. Prices on request.

PLASTIC ENGINEERING AND SALES CORP.

P. O. BOX 1037 FORT WORTH, TEXAS

New Members —

(Continued from Page 8)

FOREIGN

BUSBY, A. H. W., The Consolidated Mining & Smelting Co. of Canada, Ltd., Res. & Dev. Division, Trail, B. C., Canada.
FRANKOS, MICHAEL T., c/o Aramco, Dhahran, Saudi Arabia.
GIDDINGS, E. W. G., Dominion Tar & Chemical Co., Ltd., 2240 Sun Life Bldg., Dev. Department, Montreal Quebec, Canada.
ROBINSON, BRUCE A., 17 Howden Block, 716 Cambie Street, Vancouver 3, B. C., Canada.
SADOULET, MAURICE, S.A.D.E., 42 Rue Saint Gervais, Lyon (Rhone), France.
TRAGARDH, UNO, Royal Institute of Technology, Stockholm 70, Sweden.
TWEEDLE, LLOYD S., The Steel Co. of Canada, Ltd., Wilcox Street, Hamilton, Ontario, Canada.

CHANGES OF ADDRESS

(Old Address Follows New in Parenthesis)

ALABAMA

JOHNSTON, JR., THOMAS A., Aluminum Ore Company, P. O. Box 1346, Mobile 8, Alabama, (Aluminum Co. of America, 616 Johnston Bldg., Charlotte 2, North Carolina).

CALIFORNIA

BARNARD, W. E., Barnard Chemical Co., 2403 West 4th St., Los Angeles 5, California, (P. O. Box 271, Maywood, California).
FREEMAN, C. E., C. E. Freeman Co., 1401 Middle Harbor Road, Oakland, California, (1101 Second St., Berkeley 2, California).
GALLY, SIDNEY K., 1061 Mar Vista Ave., Pasadena 6, California, (219 So. Wilson Ave.).
GROSS, WM. F., Narmco, Inc., 1882 Moore Street, San Diego, California, (Tretolite Co., 937 Pacific Ave., St. Louis 19, Missouri.
MURPHY, ASHLEY T., Corps Engineers, U. S. Army, P. O. Box 17277, Foy Station, Los Angeles, California, (Faidley Bldg., Omaha, Nebraska).
OTT, LAWRENCE H., 1245 East Foothill Blvd., Altadena, California, (Rheem Mfg. Co., 7600 S. Kedzie Ave., Chicago, Illinois).

GEORGIA

MITCHELL, MARVIN G., Chicago Bridge & Iron Co., 507 Healey Bldg., Atlanta, Georgia, (1308 Hunt Bldg., Tulsa, Oklahoma).

ILLINOIS

BLUNDELL, EDWIN L., The American Tel. & Tel. Co., 422 S. 5th St., Springfield, Illinois, (7 East Clinton, Joliet, Illinois).
CLANCY, J. J., 505 Margate Terrace, Deerfield, Illinois, (Koppers Co., 122 So. Michigan Ave., Room 2040, Chicago, Illinois).
FOWLER, EDWARD F., 550 Galena Blvd., Aurora, Illinois, (Public Service Co., 50 Fox St.).

INDIANA

LEE, ROBERT H., 915 Forest Blvd. So. Drive, Indianapolis 20, Indiana, (5860 Rosslyn Ave.).
SEAL, WM. D., Indianapolis Power & Light Company, 1230 W. Morris St., Indianapolis, Indiana, (17 N. Meridian Street).

KENTUCKY

JACKSON, C. M., Devoe & Raynolds Co., 223 North 15th St., Louisville, Kentucky, (Rutherford and Delacey Sts., Newark, New Jersey).

LOUISIANA

BROWN, VERNON M., 627½ Cleveland, Lake Charles, Louisiana, (Columbia Southern Chemical Corp., Box 900).
MILTENBERGER, GUSTAVE, 1224 Louisiana Ave., New Orleans, 15, Louisiana, (Southeast Distributors, Inc., 636 Carondelet St.).

MICHIGAN

GREEN, DONALD R., Consumers Power Co., 519 Wheaton Ave., Kalamazoo, Michigan, 153 Rose).

MISSISSIPPI

BRANTON, JAMES A., 1025 Gill St., Columbia, Mississippi, (717 Kirby, Shreveport, Louisiana).

MISSOURI

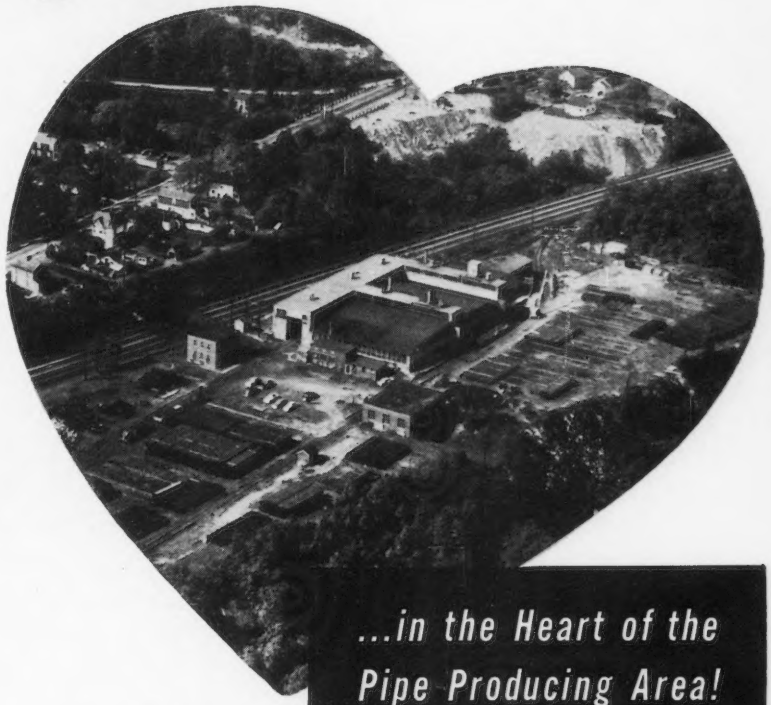
FLEMING, TOM L., American Telephone & Tel. Co., Room 1531, 324 East 11th St., Kansas City 6, Missouri, (522 Olive St., St. Louis, Missouri).
WERNER, DANIEL R., American Tele. & Tel. Co., Room 1518, 324 East 11th St., Kansas City 6, Missouri, (20 No. Wacker Dr., Chicago 6, Illinois).

NEW JERSEY

EPSTEIN, LEONARD, Canterbury Gardens, Apt. 27A, Ridge Road, No. Arlington, New Jersey, (801 West End Ave., New York 25, New York).

(Continued on Page 10)

PLS SERVICE FACILITIES AT GLENWILLARD, PENNA.



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Here we have the very latest modern equipment, including drying ovens, grit cleaning machines, thermostatically-controlled melting kettles, and automatic electrical inspection units, all of which are especially designed to assure the finest protection against underground corrosion.

When your pipe is cleaned, primed, coated and wrapped by P L S, you know you have dependable protection.

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Pioneers in Steel Pipe Protection

General Office and Plant: Franklin Park, Illinois

Plants at Glenwillard, Penna.; Longview, Texas; Corpus Christi, Texas; Harvey, La.; Sparrows Point, Md.

21 Years of Dependable Service

Changes of Address –

(Continued from Page 9)

REICHARD, EDMUND C., Box 82, Holmdel, New Jersey, (American Smelting & Ref. Co., Central Research Lab., Barber, New Jersey).

STUART, JR., LINDEN, Stuart Steel Protection Corp., 2 Mark Road, Kenilworth, New Jersey, (970 Hillside Ave., Plainfield, New Jersey).

NEW YORK

DAVIS, RUSSELL L., California-Texas Oil Co., 551 Fifth Avenue, New York, New York, (4114 West 10th St., Vancouver, B. C., Canada).

McDERMOTT, FRANKLIN, Lever Brothers Co., 390 Park Ave., New York 22, New York, (80 Varick St.).

SHAW, GEORGE KENDALL, Stauffer Chemical Co., 420 Lexington Ave., New York 17, New York, (Research Dept., Chauncey, New York).

WATSON, JR., JOHN A., 166 Garfield Place, Brooklyn 15, New York, (Minnesota Mining & Manufacturing Co., 700 Grand Ave., Ridgefield, New Jersey).

NORTH CAROLINA

BROOKE, W. G., American Telephone & Tel. Co., Liberty Life Bldg., Room 302, Charlotte, North Carolina, (208 N. Caldwell St.).

OHIO

DAYMUDE, JOHN F., Box 386, Werk Rd., R. R. No. 12, Cincinnati 33, Ohio, (3715 Highpoint Ave.).

REYS, JOHN, Falls Industries, Solon, Ohio, (National Carbon Div., Union Carbide & Carbon Corp., 30 East 42nd St., New York).

OKLAHOMA

BOSLEY, SAMUEL E., 2949 East 22nd St., Tulsa 5, Oklahoma, (1206 S. Xanthus St.).

BRADY, HUGH A., Pipeline Maintenance Corp., P. O. Box 1424, Tulsa, Oklahoma, (5739 E. 7th Street).

HORTON, ROY, Research Control Instrument Co., P. O. Box 5035, Tulsa, Oklahoma, (8211 E. 7th Street).

WHITE, ROBERT P., H. C. Price Co., P. O. Box 1111, Bartlesville, Oklahoma, (Box 263, Harvey, Louisiana).

PENNSYLVANIA

SMITH, ROY B., Sundale, Erwinna P. O. Pennsylvania, (2000 Spruce St., Philadelphia 3, Pennsylvania).

WAGNER, JR., JOHN, 3343 W. School House Lane Philadelphia 44, Pennsylvania, (Keystone Pipe Line Co., 260 So. Broad St.).

TENNESSEE

WRAY, T. CECIL, Nashville Gas Co., 81 Church St., Nashville, 3, Tennessee (8 Church St.).

TEXAS

BILLINGS, THOMAS J., Thornhill-Craver Company, Box 1184, Houston, Texas, (111 Lockwood).

CROWE, RAYMOND H., Transcontinental Gas Pipe Corp., P. O. Box 296, Houston, Texas, (905 M & M Building).

DAVIS, JAS. A., 2509 West Berry Street, Fort Worth 9, Texas, (2504).

EXUM, JR., JAMES P., United Gas Corporation, P. O. Box 2830, Beaumont, Texas, (Apt. 1, 990 14th St.).

MILLER, HARRY J., 4223 Emerson Ave., Dallas 5, Texas, (Amercoat Corp., 4554 N. Broadway, Chicago 40, Illinois).

QUINN, JOHN A., 2907 Brazos, Houston, Texas, (511 Drew Street).

REEVES, B. M., 309 Bonnie Brae, Denton, Texas, (2202 Pine Crest Dr., Marshall, Texas).

RICE, R. J., The International Nickel Co., Inc., 1503 Commerce Bldg., Houston 2, Texas, (1107).

SLOVER, CHARLES L., Reilly Tar & Chemical Corp., P. O. Box 6615, Dallas 19, Texas, (3951 Buena Vista, Apt. 2).

STEINBERGER, CHESTER, 1101 Sterling Bldg., Houston 2, Texas, (312 Rusk Building).

FOREIGN

FLORES, ING. LEOPOLDO NETTEL, E. Carranza, 1012 Ote. 2do. Piso., Tampico, Tamps., Mexico, (Petroleos Mexicanos, Refineria De C. Madero, C. Madero, Tamps, Mexico).

GROUNDS, LEO R., Vallarta No. 1, Suite 305B, Mexico D. F., (4620 Laurel, Bellaire, Texas).

LOBO, JR., HUMBERTO, Fabricas Protexa S. A., Apartado 1141, Monterrey, N. L., Mexico, (Zuazua 919 Sur Desp. 304).

ACIPCO PIPE *Resists* CORROSION

Mono-Cast Centrifugal Cast Iron Pipe
High resistance to Soil Corrosion

Used extensively for:
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Mono-Cast Alloy Iron
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Centrifugally Cast Steel Tubes
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American Cast Iron Pipe Company

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New Corporate Members of NACE

American Zinc, Lead & Smelting Co., Metallurgical Dept.
St. Louis, Missouri
Robert Ammon, Representative

O. R. Burden Construction Corp.
Tulsa, Oklahoma
O. R. Burden, Representative

Knapp Mills, Inc.
Long Island City, New York
Alfred P. Knapp, Representative

Metallizing Engineering Co., Inc.
Long Island City, New York
R. J. McWaters, Representative

Midwest Pipeline Service Co. of Mission, Kansas
Houston, Texas
S. U. McGary, Representative

Pabco Products Inc.
San Francisco, California
Maury Millar, Representative

Weston Electrical Instrument Corp.
Newark, New Jersey
Miles Kunz, Representative

Papers Solicited

A symposium on "Instrumental Methods of Analysis in the Non-Ferrous Industry," is planned for Chicago in May 1952 by the American Association of Spectrographers.

Contributed papers in this field will be welcomed. Address inquiries to Robert Raisig, Chairman Symposium Committee, c/o Apex Smelting Company, 2537 West Taylor St., Chicago 12, Ill.

NEW PRODUCTS —Materials—Service—Literature

D. W. Haering & Co., P. O. Box 6037, Harlandale Station, San Antonio, Texas has available its 44-page book, "Organic Methods of Scale and Corrosion Control," which may be obtained by request on company letterhead. The company also is distributing a 1952 H-O-H Calendar, featuring a four-color lighthouse scene.

•

American Brass Company, Waterbury 20, Connecticut offers the following publications: Publication B-3 Machining Copper and Copper Base Alloys, which deals with fabrication of these materials and contains data on compositions, physical constants and coolants. Publication B-14 Anaconda Free Cutting Brass Rods, deals with alloy rods for screw machine use. It includes physical constants and properties of 46 free cutting and general purpose rods.

•

Magnesium Sales Department, The Dow Chemical Company, Midland, Mich. has assumed distribution of cathodic protection products formerly handled by Dowell Incorporated, a wholly-owned subsidiary. W. S. Loose is salesmanager of the magnesium department; **H. A. Humble** is manager of Dow's Cathodic protection sales and R. **L. Featherly** will assist him.

•

Ramtite Co., Division of the S. Obermayer Co., 2563 West 18th Street, Chicago 8, Ill., has published a 24-page reference catalog "Boiler Settings with Plastic and Castable Refractories," which contains drawings, charts and other data on boiler settings.

•

Metalweld, Inc., 26th and Hunting Park Ave., Philadelphia 29, Pa. has published a folder outlining the various services offered by the company in the corrosion control field.

•

Vorac H-400, a zinc chromate, Vinylite resin-base wash coat primer is manufactured by The Vorac Company, 162 East 38th St., New York. The primer may be used under nearly all kinds of coatings on a clean surface, providing protection against corrosion until finishing coats can be applied. It requires no oxidation or polymerization, forming a film by solvent evaporation. It may be used under some conditions as a substitute for phosphate treatment and should not be applied over a phosphated surface.

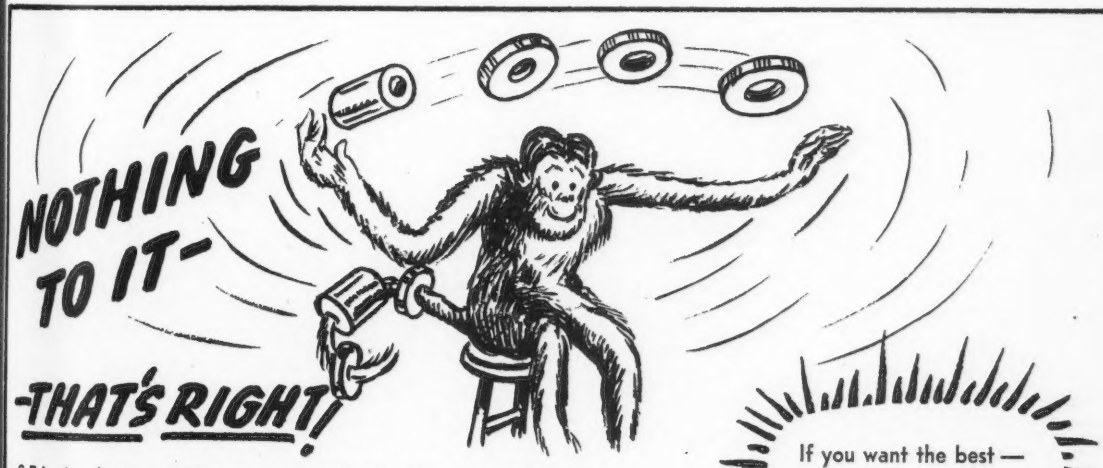
•

Koppers Co., Inc., is completing new research laboratories at Verona, Pa. where an enlarged unified program is contemplated. Employment of nearly 200 chemists, physicists, engineers and technicians by 1953 is projected. The laboratories will provide considerable space for pilot plant investigations in chemicals, fuels and improvement of large machinery. **Dr. F. G. D'Alelio** is manager of Koppers research department. Koppers also has established a professorship and six fellowships at three Pittsburgh schools. At Carnegie Institute, the Becker Professorship in Organic Chemistry is being sponsored as a tribute to **Dr. Joseph Becker,** vice-president and general manager of the company's engineering and construction division. **Dr. Robert W. Carlin,** first to hold the professorship is directing also two Koppers-sponsored fellowships at Carnegie Tech for research in organic chemistry. Two fellowships at Duquesne University in fundamental organic chemistry and two fellowships at Pennsylvania State College for Women also have been set up.

•

Magnus Chemical Company, Garwood, N. J. has developed a new type of steam cleaning compound which contains no alkaline salts. It is a non-conducting material, a factor which makes it valuable in cleaning electrical apparatus. Neutral in reaction, it will not streak or dull good paint, the manufacturers say and it is non-corrosive. Aluminum and other light-non-ferrous metals attacked by alkaline salts are untouched by Magnus 72. Generating no objectionable fumes, it can be used indoors where ordinary steam cleaners cannot be employed. Its unsaponified oil content tends

(Continued on Page 12)



If you want the best—
SPECIFY S.E.I.

S.E.I. Insulating bushings are made to these specifications:

1. Tightening torque 100 ft. lbs.
2. Bending resistance 200 ft. lbs.
3. All are pressure tested to 140 p.s.i. air for porosity.
4. Tensile strength over 4000 lbs.
5. Threads A S A pipe standards, tolerance only plus or minus ½ thread from gauge.

FOR ADDITIONAL INFORMATION
PHONE . . . WIRE . . . WRITE

SERVICE ENGINEERS, INC.
Manufacturers of Industrial Plastic Products
3030 W. Pafford P. O. Box 11068 Fort Worth 9, Texas

New Products—

(Continued from Page 11)

to prevent formation of rust on unprotected metal surfaces. Acting as fast as other commercial steam cleaning compounds, the liquid concentrate material is easily mixed with water and does a good job where dirt is mixed with grease.

•

Wilbur & Williams Co., 130 Lincoln St., Brighton 35, Mass. will send a one-half pint sample of its new combination inhibitive primer and finish coat to industrial users requesting it on their letterhead. Normally drying in 10 to 15 minutes, the material has many of the rust inhibitive features of Totrust, in addition to weather resistant features usually associated only with baked coatings. Adhesion is claimed to be excellent even on aluminum and galvanizing.

•

Seamless Cast Polyethylene tubing in diameters from 2¾-inch to 20 inches, in standard lengths of 48 inches is available from American Agile Corp., P. O. Box 168, Bedford, Ohio. Joints can be connected by hot gas welding. The tubing's specific gravity is .92 and it has high impact strength.

•

Reilly Tar and Chemical Corp., 1615 Merchants Bank Bldg., Indianapolis, Ind. offers copies of its new 24-page booklet on coatings for metal surfaces exposed to corrosion, tuberculation and incrustation. It covers hot application enamels, primers and coupling compounds, cold application enamels and bituminous paint and the properties, uses, containers, performance tests and application procedures for coatings; handling, storage and inspection of protected surfaces plus field notes on application which include quantities of enamel required for various pipe sizes.

•

Pittsburgh Coke & Chemical Co. has opened an office at 75 East Wacker Drive, Chicago.

•

Plax Corp., Hartford, Conn. announces the Interstate Commerce Commission has approved shipment of electrolytic acid or corrosive battery fluid in polyethylene bottles up to one quart. Fiberboard boxes packed to prevent movement of the bottle are specified.

•

Nickel Alloy Steel Castings in Industry, a 32-page booklet produced by The International Nickel Co., Inc., Dept. EZ, 65 Wall Street, New York, illustrates the applications of nickel alloys in a wide variety of industrial applications. Tables give selection of compositions and specifications values.

•

Pydraul F-9, a non-flammable type, noncorrosive, chemically stable hydraulic fluid is described in a 12-page booklet available from Monsanto Chemical Company, St. Louis 4, Mo. The fluid, developed primarily for use in die-casting machines, hydroelectric turbines, glass drawing machinery and hydraulic presses is finding other applications where flammable fluids are a hazard. It can be operated continuously at temperatures up to 300 degrees F without breakdown. It has high corrosion and oxidation stability, having negligible effect on copper and no effect on iron, aluminum and magnesium.

•

Flintkote Company's Industrial Products Division, 30 Rockefeller Plaza, New York 20, N. Y. has issued a 24-page pocket sized illustrated booklet in which is described the company's asphalt emulsions and cutbacks, asphalt, rubber and resin adhesives and coatings and sealers.

•

Black Velvet Conveyers, manufactured by Oral T. Carter and Associates, Inc., 1704 Dreman St., Cincinnati 23, Ohio, have all bearings and working parts of wheels and rollers treated with a deep penetrating oil for self-lubrication and to prevent rust.

•

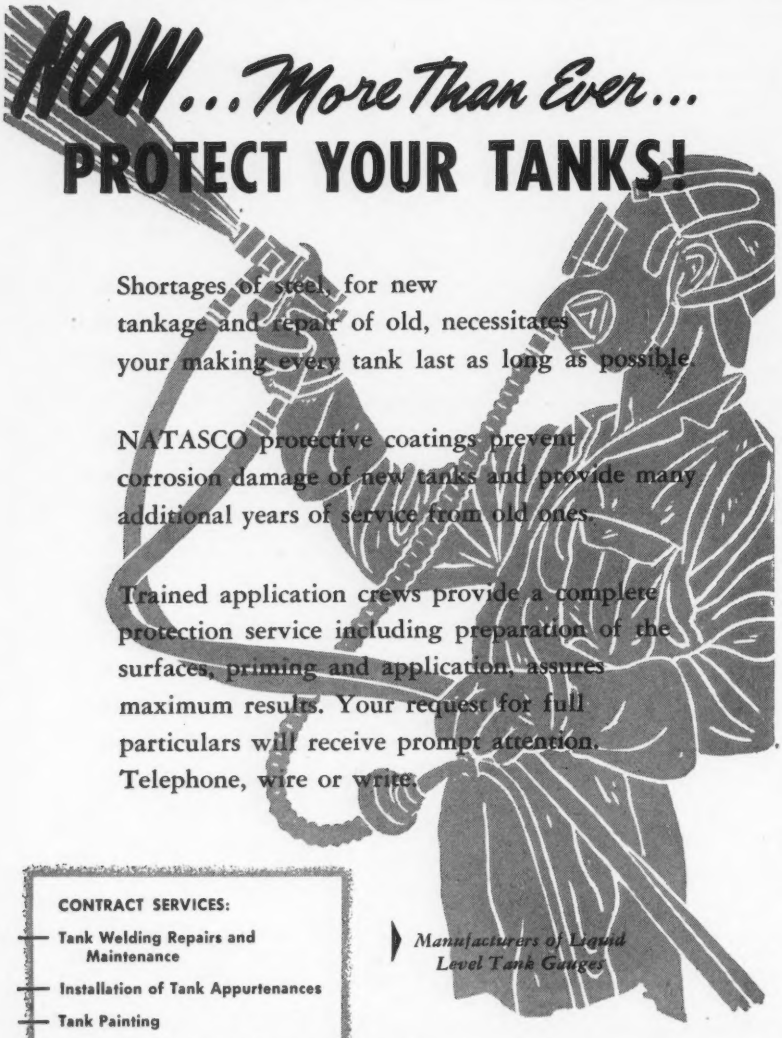
Zinc as an anode material is the topic of a 40-page booklet available from Federated Metals Division, American Smelting and Refining Co., 120 Broadway, New York 5, N. Y. The publication, prepared for the American Zinc Institute by Ebasco Services tells when zinc can be expected to give most satisfactory results and how to install it.

•

Stuart Steel Protection Corp. (Stepcol), formed to sell anodes and other cathodic protection equipment, cold coatings and other specialty products for severely corrosive conditions has established offices at 2 Mark Road, Kenilworth, N. J. **Linden J. Stuart, Jr.,** is president. Mr. Stuart formerly was with Barrett Division of Allied Chemical & Dye Corp.

•

Information about membership in NACE will be sent on request to persons interested.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PROTECT YOUR TANKS!
Shortages of steel, for new tankage and repair of old, necessitates your making every tank last as long as possible.
NATASCO protective coatings prevent corrosion damage of new tanks and provide many additional years of service from old ones.
Trained application crews provide a complete protection service including preparation of the surfaces, priming and application, assures maximum results. Your request for full particulars will receive prompt attention. Telephone, wire or write.
CONTRACT SERVICES:
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Tank Painting
Application of Protective Coatings
Tank Cleaning — BS&W Emulsion Chemical Treating
Manufacturers of Liquid Level Tank Gauges
PROTECTS TANKS AGAINST CORROSION
THE Natasco COMPANY
P. O. BOX 1318 TULSA, OKLAHOMA
Lease Tank Service—West Texas Area:
Williams Construction Company
Odessa, Texas
California Representative:
Coast Contractors, Inc.
2627 Atlantic Ave., Long Beach 6, Cal.

when water pressure means the most

City officials, municipal and industrial engineers shoulder a tremendous responsibility in the maintenance of water pipe lines. They know that pressure failure due to leakage or tuberculation can often have disastrous results. Today, the neglect of water lines—however old—is uneconomic. The Centriline process of centrifugally applying cement-mortar lining to pipe lines *in place* virtually makes new pipes out of old at a fraction of the cost. Centrilining, not only prevents tuberculation and leakage, but totally eliminates corrosion to the inner walls. Pumping costs are lower, maintenance reduced and the saving over new pipe lines often amounts to many thousands of dollars. Write today for your free copy of our new bulletin describing the Centriline process.

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CENTRILINE CORPORATION

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Branch Offices in Principal Cities of United States and Latin America

ON THE WEST COAST, WRITE AMERICAN PIPE & CONSTRUCTION CO., P. O. BOX 3428, TERMINAL ANNEX, LOS ANGELES, CALIFORNIA

PERSONALS

Jesse H. Plummer, vice-president of Glass Fibers, Inc., has been appointed general factories manager of the firm.

•

Peter C. Reilly, founder and president of Reilly Tar & Chemical Corp., died January 4 in St. Vincent's hospital, Indianapolis. He was almost 83 years of age. The recipient of many honors from schools, universities and organizations of which he was benefactor, he was a pioneer in the modern method of preserving utility poles and railroad ties and known for his ability to infuse new life into ailing businesses.

•

A. L. Forbes, elected president of the Pipe Line Contractors Association of America at its Houston convention Wednesday, January 9, died of a heart attack in an airplane en route to New York City the following day. For more than 20 years he worked for oil companies in the Houston area before becoming vice-president of Pressure Welding Company of Texas. He founded Associated Pipe Line Contractors, Inc., in Houston in February 1946. He was a member of NACE.

•

Frank E. Miller has been named manager of the Eastern Division of Hills-McCanna Company of Chicago, with offices in New York City.

•

Edward J. Detgen has been named sales manager of the General Products Division of Owens-Corning Fiberglas Corp. with headquarters at Toledo, Ohio.

•

John M. Thomas, manager of the pipeline division of H. C. Price Co., has been named a vice president. **Elmer L. Gallery,** formerly secretary-treasurer, has been advanced to the position of vice president and treasurer and **John P. Overton,** assistant treasurer, has been named secretary of the company.

•

Grover C. Hansen, manager of sulfuric acid production at Grasselli Chemicals Department of the Du Pont Co. at Wilmington, Del., retired January 1 after more than 40 years with the department. **Alvin A. Corey** will take his place.

•

Raymond W. Capaul has been elected vice president and general sales manager of Glass Fibers, Inc. **F. J. Solon** was elected vice president—advertising and public relations.

•

Dr. William Blum, internationally known for his contributions to the field of electrochemistry, has retired as Chief of the Electrodeposition Section of the National Bureau of Standards after 42 years service. Responsible for NBS research and development in electrochemistry since 1929, Dr. Blum came to the bureau in 1909 and has done research in electrodeposition, including electroplating, electrotyping and electroforming. He also has made contributions in the field of analytical chemistry. He has been succeeded by **Dr. Abner Brenner,** who has been engaged in electrodeposition work at the bureau since 1930, except for two years spent at NBS laboratories in California.

(Continued on Page 16)

A regular service of The **COOPER ALLOY** Foundry Co., Hillside, N. J.

CA TECHNICAL TOPICS

WELDING STAINLESS ALLOYS

Norman S. Mott
Chief Chemist and Metallurgist
The Cooper Alloy Foundry Co.

In the welding of stainless alloys, four types of composition have to be taken into consideration—the hardenable martensitic straight chromium group; the non-hardenable ferritic straight chromium group; the corrosion resisting chromium-nickel group, and the heat resisting chromium-nickel group. These alloy compositions have, in varying degrees, greater thermal expansion and lower thermal conductivity than carbon steels, and in some instances have carbide mannerisms which affect corrosion resistance.

When the torch flame or arc is applied, the metal is heated to a very high temperature only in the area being welded. The heated metal expands and tends to push out in various directions against the colder surrounding metal, producing severe internal stresses. When the heat source is removed, the resultant contraction produces pulling stresses acting between the cooling and the cold metal. If the metal does not have sufficient ductility to stretch and accommodate itself to these great stresses, cracking will result. This is most prevalent in the lower ductility straight chromium grades. By making temperature gradients as gradual as possible, this danger can be minimized.

In the chromium-nickel corrosion resisting alloy types, a form of grain boundary carbide precipitation occurs during welding. To offset the dangers of intergranular corrosion, these carbides must be put into solution by subsequent heat treatment before the welded metal is put into use.

Difficulties which are involved in welding cast stainless steel can be overcome through the use of pre-welding and post-welding thermal treatments as indicated at right. Alloys for heat resistance applications usually do not require any thermal treatment after welding.

Alloy	Remarks
5% Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1650° F. . . . hold for 1 hour, furnace cool to 1350° F., hold for 2 hours, then air cool.
9% Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1350° F. . . . hold for 2 hours, then air cool.
12% Cr	Preheat to 400° F. or over. After welding, cool to not less than 300° F. then heat to 1350° F. . . . hold for 4 hours, then air cool.
16% Cr	Preheat to 250-300° F. After welding, cool to 250° F. or lower, then heat to 1450° F. . . . hold for 4 hours, then air cool.
18% Cr	Preheat to 250-300° F. After welding, cool to 150° F. or lower, then heat to 1450° F. . . . hold for 4 hours, then air cool.
27% Cr	Preheat to 250° F. or over. After welding, heat to 1650° F. . . . hold for 2 hours, then rapidly air cool. If distortion is feared stress-relieve weld for 1 hour at 1350° F., followed by air cooling.
18-8S	Preheat not required. After welding heat at 2000° F. for 1 hour, then water quench.
18-8SCb	Preheat not required, nor is post heat. However, after welding, it may be stress-relieved at 1650° F. for 2 hours followed by air cooling.
18-8SMo	Preheat not required. After welding heat at 2000° F. for 1 hour, then water quench. Sufficiently ferritic alloys can often be used without post heating.
FA20	Preheat to 400° F. After welding cool very slowly then heat to 2000° F. . . . hold for 1 hour and water quench.

Copies of this article reprinted on heavy stock for convenient filing are available on request

The **COOPER ALLOY** Foundry Co., Hillside, N.J.

Yes, we're *Always* on the lookout for Pipe Line Progress . . . and here's ANOTHER Midwestern FIRST

Yes, a pipeline OUTER WRAP made from Fiberglas. Several years ago Midwestern and Owens-Corning brought out the first Fiberglas Inner Wrap for reinforcing your coatings. Now, through our combined efforts in seeking "Progress on the Line" we again lead the field in offering this exceptional new product that gives greatly increased corrosion protection at an extremely nominal cost. This amazing new outer wrap is designed to act as an exterior protection for underground pipe line. Composed of asphalted compound with tar additives the material is reinforced in a longitudinal direction by glass fiber mat and strong Fiberglas yarn. The product helps to prevent damage to enamel during lowering-in and back-filling operations and is partcularly valuable in off-setting soil stresses. The high porosity of Fiberglas Outer Wrap reduces holidays by permitting the complete release of trapped gasses and air.

THE BENEFITS OF A FIBERGLAS REINFORCING AND AN OUTSIDE WRAP IN ONE PACKAGE.

TENSILE STRENGTH—By the use of parallel Fiberglas yarns the tensile strength is greatly increased eliminating breakage.

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STORAGE—Fiberglas Outer Wrap will withstand storage temperatures from 0° to 150° F. without deterioration.

BONDING — This Outer Wrap does more than bond . . . it fuses to the enamel becoming a permanent part of the coating.

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A PROVEN PRODUCT — Fiberglas Outer Wrap, distributed by the Midwestern Engine and Equipment Company has been accepted by many of the largest companies in both natural gas and crude products transmission lines.

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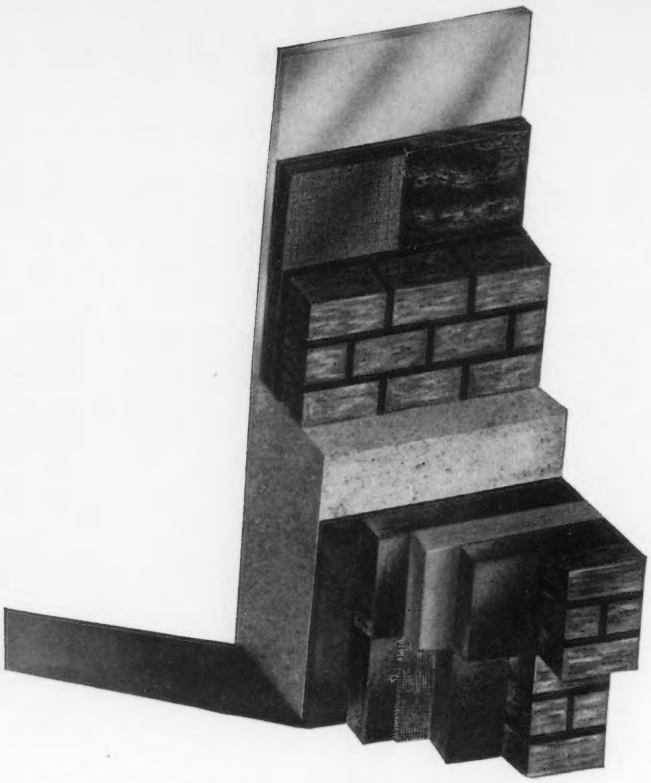

in CORROSION-PROOF LININGS . . . there is no substitute for ATLAS experience

Portrayed above are a number of ATLAS lining constructions for use on steel or concrete. Each has definite applications where it will give you the best service obtainable for your operating conditions.

ATLAS engineers have always recognized that there is no one lining material or construction best for all applications. Accordingly, for sixty years they have accumulated intensive laboratory and practical field data pertaining to most known corrosives. Over this period, they have developed materials which individually or in combined constructions offer the best long-term resistance.

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Corrosion-proof COATINGS . . . *Bulletin 7-2*

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. . . between your process and corrosion

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Corrosion-proof: Cements—Coatings—Vessel Linings

PERSONALS

(Continued from Page 14)

J. H. King, vice president of the Babcock & Wilcox Co., has been named to head the reorganized boiler division of the company.

•

Donald H. Bond, senior electrical engineer, The Texas Pipe Line Co., Houston, is on temporary leave of absence and located at the Veteran's Administration Hospital at Fort Bayard, New Mexico. His primary interest has been in corrosion work since 1935 and he has been a member of NACE since its organization in 1943. He was first secretary-treasurer of Houston Section and has served as chairman of Technical Practices Committee 3. During his service the committee has collected data on anodes for use with impressed currents and published the First Interim Report on Ground Anode Tests, NACE Pub. 50-1. Mr. Bond contemplates collection of additional data for subsequent committee reports. During the past three years he has been active in the design and development of specialized motor control equipment which has made feasible push-button operation of 1250 to 3000 HP pumping station motors and auxiliary equipment.

•

William J. Grede, president of Grede Foundries, Inc., Milwaukee, has been named president of the National Association of Manufacturers.

•

Dr. William F. Clapp, noted marine biologist, died at his home at Duxbury, Mass., December 28, 1951. He was 71. He was taken ill enroute to Europe on a scientific mission concerned with marine borers and died after returning to the United States by air. He was one of the founders of the Sea Horse Institute. He will be remembered as the banquet speaker at the NACE conference at St. Louis in 1950. The International Nickel Co., Inc., proposes to name its annual prize for papers on deterioration in marine environments the William F. Clapp Memorial Prize.

General Topics Given For Corrosion Course At University of Houston

General topics to be covered during the Houston University night course on corrosion which started January 29 and will last 16 weeks were given as follows by Joseph R. Crump, engineering professor:

First Quarter—Basic metallurgy requisite for full understanding of corrosion prevention.

Second quarter—Basic principles of electrochemistry underlying corrosion phenomena, including the nature and mechanism of corrosion and a discussion of galvanic corrosion and its detection.

Last half—Specific methods of corrosion prevention, including surface coatings, selection of materials, environmental control and cathodic protection.

Persons attending the course not for credit will be required to maintain the same standards as those taking it for credit, the university said. Classes are being held Tuesday and Thursday 8 to 9:30 pm.

The long white structure over the water is the Galveston Pleasure Pier on which both the technical sessions and exhibit will be held. Just above the landward end of the pier is a cluster of hotels including the Galvez, conference headquarters hotel.

Galveston, 1952 Conference City, Has Colorful History Dating to 1686

One of the oldest cities in Texas, Galveston has served under six flags and its citizens have helped enrich the pages of Texas history.

Galveston Island was discovered in 1686 by the French explorer, LaSalle. He named it San Luis but it remained unoccupied except by roving bands of Indians known as Caronkaways.

Early in the 18th century, Galveston, like all of what is now Texas, passed into the possession of Spain, and in 1777 the island was temporarily occupied by troops of Count Bernardo de Galvez, governor general of the Spanish possessions in America. In honor of the Spanish nobleman, the island was given the name of Galvez, being changed in later years to Galveston.

Headquarters for Pirate

In 1816, Jean Lafitte, the notorious pirate, claimed Galveston as his headquarters and made it a rendezvous for his ships and men until his acts so embarrased the government of the United States that he was prevailed upon in 1821 to move his base of operations farther southward.

When the ships of Lafitte cleared the harbor, American pioneers began to arrive upon the island and by 1830, a fair-sized settlement had been established.

The city of Galveston was founded by Col. Michael B. Menard, a Canadian who came south at the age of 25 to seek a fortune. Menard exerted a strange power over the Indian tribes and during the Texas War for Independence from Mexico, he ofttimes was able to aid the Texas armies. At the conclusion of the war in 1836, Menard purchased from the new republic an acreage comprising the eastern end of Galveston Island. He then organized the Galveston City Company, which plotted the townsite, laying out streets and setting aside suitable sites for schools, hospitals, parks and public buildings. Menard was a civil engineer by trade, and Galveston's wide straight streets show unmistakeable evidence of his skill and remarkable vision.

Port Was Opened in 1832

The earliest movement of traffic through the port of Galveston, according to old records, took place in 1832, by which time a small settlement comprising about 300 people existed on the island. Sailing ships from the North Atlantic coast brought in foodstuffs, and manufactured goods and departed with parcels of hides, pelts, wool, mohair, cattle and other farm products.

Many shipments were barged to the island via rivers and bayous, while others were transported to Galveston's bayshore by oxcarts and transferred to the island by rafts and rowboats. Thus, Galveston originally was a trading post, from which it was later transformed into a port and an important distributing center. Today, Galveston is the largest "dry cargo" port on the Gulf of Mexico, west of the Mississippi River.

It has facilities to accommodate 40 Liberty-type vessels loading or unloading at the same time. It is the world's largest sulfur port, handling about two million tons annually and in 1950 shipped more grain and cotton than any other port in the nation. Approximately 5000 persons are employed in the shipping industry in Galveston.

Borden Was Prominent Figure

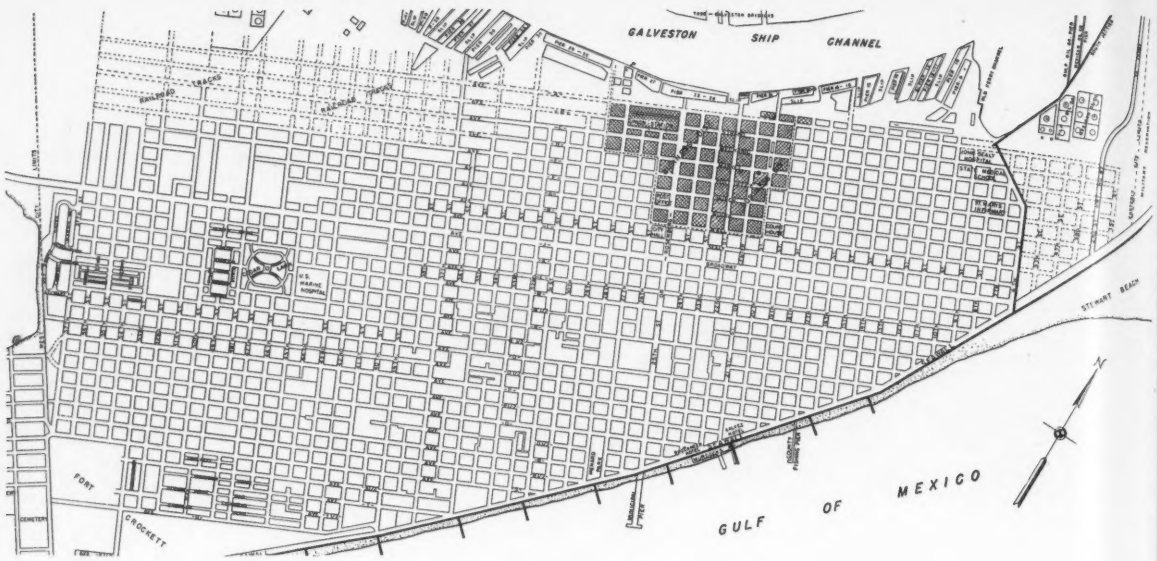
Another prominent figure in Galveston's early history was Gail Borden, of canned milk fame, who served as the first customs collector at the port. He later resigned that position to devote all his time to a milk condensing process.

During the Civil War, Galveston was the most important city in Texas. It was the port of entry through which flowed a constant stream of supplies. In 1859, the federal government planned to fortify Pelican Split, just across the channel from the city, and by the time Texas seceded from the union, had built three houses to serve a garrison. No fortifications had been constructed, but when the Confederacy took charge, earthworks were thrown up and several guns mounted.

The location was manned by Confederate troops, as was the city's east end, which also was fortified. The Southern forces improvised warships from the side-wheeler "General Rusk," and the schooner "Royal Yacht" and these two craft operated in and out of Galveston for some time. The island

(Continued on Page 18)

Advance Information on the March 10-14, 1952 Galveston Conference



This map of part of the city of Galveston shows the location of the Galveston Pleasure Pier (called "Municipal Pier" on the map) and the Galvez and Buccaneer Hotels. Houston is approximately 55 miles northwest of Galveston by highway.

Galveston—

(Continued from Page 17)

fortifications were fired upon by the Federal warship "South Carolina." On October 5, 1862, a Federal fleet appeared off the island and after firing in the city, moved into the harbor. Confederate forces were withdrawn to Virginia Point, and Galveston was captured.

At this time, the greater part of the civilian population had moved to points in the interior and business was at a standstill. The city remained in the hands of the Union Navy for nearly three months and then Gen. J. B. Magruder of the Confederate armies, in a combined rail and water attack, recaptured the city on January 1, 1863. Today, Galveston is amply protected from foreign invasion by three large government fortifications.

Great Disaster Killed 5000

Galveston's greatest disaster, however, did not occur until 37 years later, in 1900, when a combined hurricane, flood and tidal wave wiped out much of the city and killed nearly 5000 persons. The island was completely covered by water and it took many years of toil to rebuild the city.

In the year of the flood, Galveston became the first city in the nation to adopt the city commission form of government, now in wide use. After several years of planning, the development and construction of Galveston's famous seawall to prevent recurrence of the 1900 disaster began. The seawall is now 7½ miles long and a three-mile extension to cost about $8,000,000 was started last fall.

The present population of greater Galveston is 71,000. It is a modern city in every respect with wide, paved boulevards, beautiful tropical foliage, modern schools, churches, residences and commercial establishments.

As a resort and convention city, Galvestonians feel it is one of the finest in the southwest. Its beaches yearly attract thousands and thousands of tourists and its annual Splash Day, held on the first Sunday in May, to mark the official opening of the summer season, attracts nearly 100,000 people.

NACE Members Asked To Submit Questions To Two Round Tables

Members of NACE are invited to submit questions to be answered at the concurrent round tables on corrosion to be held on the morning of March 14 at Galveston during the Eighth Annual Conference and Exhibition. Reply postcards were sent to all members during January requesting questions.

Questions on pipe line matters and underground corrosion should be addressed to the Pipe Line and Underground Corrosion Round Table, chairman of which is Kark H. Logan, Cast Iron Pipe Research Institute, Washington, D. C. and co-chairman of which is O. C. Mudd, Shell Pipe Line Company, Houston. These questions, if possible should be on the post card provided, but in any case should be addressed to Central Office NACE, 919 Milam building.

Questions on general corrosion problems should be addressed to the General Corrosion Problems Round Table, chairman of which is R. B. Hoxeng, U. S. Steel Company, Pittsburgh, Pa. and co-chairman of which is Frank L. Whitney, Jr., Monsanto Chemical Company, St. Louis.

Persons submitting questions are urged to be sure they indicate the round table to which it should be addressed.

Round table discussions held at previous meetings of the association have been among the best attended technical events on the program.

Mexican National Railways Offers Tour

Sponsored by the National Railways of Mexico a nine-day all-expense cost Mexico City tour will be offered to delegates, their families and friends at the close of our Galveston meeting. The railroad company assures that no efforts will be spared in providing the utmost comfort and enjoyment.

In addition to coach or Pullman accomodations in fine equipment, lodging will be at modern, first class hotels during a five-day stay in Mexico City; wholesome meals served at good restaurants, and the daily sightseeing trips under the direction of English-speaking guides.

While in Mexico City, Cuernavaca, Taxco and Puebla visits will be made to famous cathedrals, ancient pyramids, colorful markets, modern business and residential districts. In fact, every place of interest is included.

Among other attractions there will be a canoe ride through the flower-decked canals of the Floating Gardens of Xochimilco and a bullfight in Mexico City.

Mexico, a foreign land just a step away from Galveston is awaiting you! Take advantage of this delightful tour at an amazingly low cost. For detailed information write to Mr. F. Alatorre, General Agent, National Railways of Mexico, 2401 Transit Tower, San Antonio 5, Texas.

Advance Information on the March 10-14, 1952 Galveston Conference

Presentation of NACE Awards Due At Annual Banquet

Presentation of the 1952 NACE Awards will be made at the annual banquet which will be held on Thursday, March 13 at Galveston, Texas during the Eighth Annual Conference and Exhibition. Hand scribed certificates will be awarded to Earl A. Gulbransen, who will receive the Willis Rodney Whitney Award and to Starr Thayer, who will receive the Frank Newman Speller Award. The awards will be the first made under the revised procedure adopted by the association's board of directors in 1950. The procedure was revised by a committee headed by F. L. LaQue, with the collaboration of the Policy and Planning Committee, E. P. Noppel, chairman.

In reporting the decision of the 1952 Awards Committee, Vance N. Jenkins, who as past president is automatically chairman of the committee, said the list of persons eligible for the awards was imposing. Elimination was accomplished by a committee meeting during the 1951 conference in New York and subsequently by correspondence. Two ballots only were necessary to select the recommended recipients, Mr. Jenkins reported. The committee's recommendations were approved by the board of directors at its November 30, 1951 meeting at Houston.

Mr. Jenkins said he intends to suggest revisions of committee procedure which would give it greater time for deliberations.

Members of the committee were R. L. Bullock, I. C. Dietze, A. H. Gropp, W. C. Honecker, R. B. Hoxeng, V. V. Kendall, R. B. Mears, Oliver Osborn, Ivy M. Parker, F. A. Rohrman, L. R. Sheppard, H. M. Trueblood, E. W. Vereeke and F. L. Whitney, Jr.

Recipients of the awards in former years were.

Whitney Award

1947—Willis Rodney Whitney
1948—Ulick R. Evans
1949—R. B. Mears
1950—R. H. Brown
1951—Herbert H. Uhlig

Speller Award

1947—Frank Newman Speller
1948—John M. Pearson
1949—F. L. LaQue
1950—O. C. Mudd

Galveston Accessible From City of Houston

Galveston is easily accessible by road and railroad. The new multimillion dollar Gulf Freeway, a no-grade crossing highway connecting Houston with Galveston is expected to be completed before March. This highway gives ready access to Galveston from Houston.

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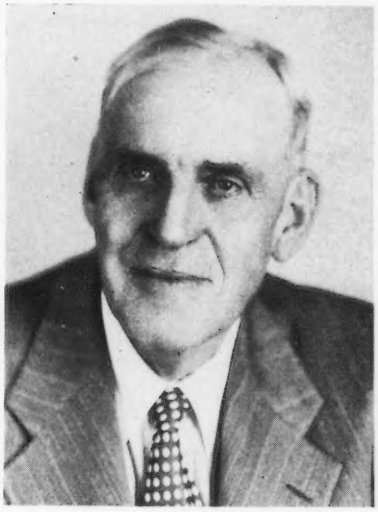
Technical papers presented at national meetings of NACE are usually published in Corrosion after review and approval by the association's editorial review committee and the editor of Corrosion.

Named to Receive NACE Awards



STARR THAYER

EARL A. GULBRANSEN

Protecting Underground And Underwater Steel Is Thayer's Field

Starr Thayer, since 1937 a corrosion consultant with offices at Houston, Texas has been named to receive the 1952 Frank Newman Speller Award for achievement in the field of corrosion engineering. Mr. Thayer is among the first engineers to apply cathodic protection to underground structures. His consulting work has been in all sections of this country and in several foreign countries.

His principal interest is in the protection against corrosion of underground and underwater pipelines, tanks and docks. He has performed engineering work on many large cathodic protection systems since beginning with one small unit in 1931.

Mr. Thayer was employed as corrosion engineer by the United Gas System from 1930 to 1937 when he resigned to become a consultant.

A 1908 graduate of Iowa State College in electrical engineering, he was first engaged in the construction of electric plants, power and distribution systems and electric railways.

He has contributed numerous articles on cathodic protection to the early literature on this subject.

Mr. Thayer, who was one of the early members of NACE, not only participated in the formation of the association, but participated in the first corrosion control group known as the Midcontinent Cathodic Protection Association. This led to the formation of NACE which was organized in 1943 and incorporated in 1945.

•

NACE now has over 3000 members.

Gulbransen's Interests Include Reactions At High Temperatures

Earl A. Gulbransen, advisory engineer to Westinghouse Research Laboratories in East Pittsburgh, Pa. has been named to receive the Willis Rodney Whitney Award for achievement in the field of corrosion science. His principal scientific interests are the combustion of carbon and reactions of metals and alloys at high temperature with oxygen, solid phase reactions, protection and corrosion, electron diffraction and microscope study of crystal and secondary structure of surface films and others.

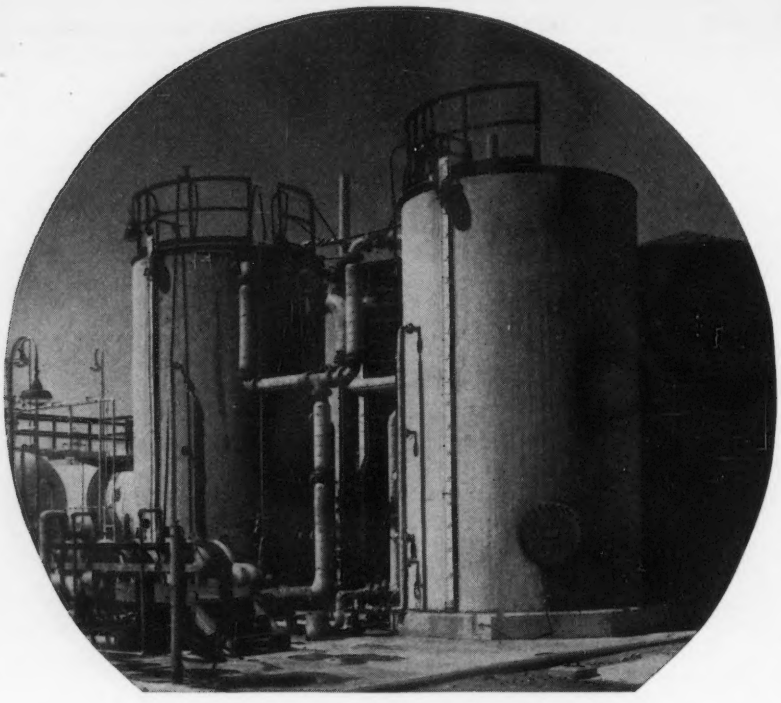
In July 1940 he joined Westinghouse Research Laboratories to initiate a new research program on reactions of metals, alloys and other materials with oxidizing and reducing atmospheres especially at high temperatures. He also has acted as consultant to the Lamp Division and Atomic Power Division on the new metals; to the electronics department, metallurgical department, chemical department and combustion department of the laboratory, as well as other groups in his company.

Developed Microbalance

During the war, Mr. Gulbransen acted as consultant on new methods of underwater propulsion, including rocket and jet, primary batteries, chemical power plants and gas turbines.

His principal project has been the study of gas-metal and solid phase reactions. For this purpose he was active in the development of a very sensitive microbalance for the study of reaction kinetics and in development of a special electron diffraction camera for the study of surface structure of materials up to

(Continued on Page 20)



How SHELL protects glycerine from contamination

The Shell Chemical Corporation is manufacturing glycerine by a synthetic process at its plant in Houston, Texas. There were two problems associated with the intermediate storage of the product. *First,* it was essential that the glycerine *not* be contaminated by metallic corrosion during storage. *Second,* the temperature of the glycerine had to be maintained.

Shell solved the first problem by having Chicago Bridge fabricate the tanks out of nickel-clad steel. The second problem was solved by insulating the tanks with magnesia.

The two tanks, which were built in our Birmingham plant, are of butt-weld construction. They are smooth, easy to insulate and have no rough edges where corrosion can start.

Nickel is only one of several corrosion-resistant alloys that we know how to handle. We also fabricate and erect structures made from:

- *CLAD STEELS*—Chrome-nickel or straight chrome stainless, or monel.
- *LININGS*—Chrome-nickel or straight chrome stainless steel, monel or everdur.
- *SOLID CORROSION-RESISTANT METALS*—Chrome-nickel or straight chrome stainless steel, monel, aluminum or everdur.

We also can supply storage tanks and other equipment made of plain carbon steel. Write our nearest office for estimates or quotations when you need plate structures of any type.

CHICAGO BRIDGE & IRON COMPANY

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Boston 10.....1060—201 Devonshire Street
Chicago 4.....2119 McCormick Building
Cleveland 15.....2248 Guildhall Building
Detroit 26.....1561 Lafayette Building
Houston 2.....2159 C & I Life Building
Los Angeles 17..1552 General Petroleum Building
New York 6.....3328—165 Broadway Building
Philadelphia 3 1661—1700 Walnut Street Building
San Francisco 4.....1572—200 Bush Street
Seattle 1.....1363 Henry Building
Tulsa 3.....1640 Hunt Building
Washington 6, D. C.....1166 Cafritz Building

Plants in: BIRMINGHAM, CHICAGO, SALT LAKE CITY, and GREENVILLE, PA.

Gulbransen—

(Continued from Page 19)

1000 degrees C. The microscope also has been used for study of chemical reactions on solid materials.

Native of Seattle

Mr. Gulbransen was born in Seattle, Washington January 20, 1909, educated in Seattle public schools and graduated with honors from the State College of Washington, Pullman, in June 1931 with a BS in chemical engineering and minors in physics, physical chemistry and mathematics. While a graduate assistant at the University of Pittsburgh 1931-34 where he obtained a PhD in physical chemistry, he taught courses in physical and organic chemistry.

His thesis work was concerned with the thermodynamic properties of dilute solutions of electrolytes. In connection with this work he developed the first high precision adiabetic differential calorimeter in America.

He took additional work at University of Michigan in physics and mathematics in 1932, 1937 and 1939. In 1934 he was tendered a National Research Council doctorate fellowship at the University of California in Berkeley where until 1936 he continued work in thermodynamics of solutions and especially in non-aqueous solvents.

He also worked in the low temperature laboratory determining the data of state equation for several gases.

During 1936-40 he was instructor in chemistry and chemical engineering at Tufts College, Medford, Mass. with advanced courses in physical chemistry, thermodynamics and chemical engineering. He also started a research program on the geochemical and geophysical processes occurring in nature by studying the abundance of ratios of the isotopes using the mass spectrometer.

Published Many Papers

Over 50 of his papers have been published in the journals of the American Chemical Society, Electrochemical Society, American Association for the Advancement of Science, Electron Microscope Society, American Crystallographic Society, American Institute of Mining and Metallurgical Engineers, Sigma Xi, Phi Lambda Upsilon and American Men of Science and others.

He has had the following honors and distinctions: Chairman of national meetings of Electron Microscope Society and American Society for X-Ray and Electron Diffraction, and of International Conference on Surface Reactions 1948; chairman and organizer of Gordon Research Conference on Chemistry and Physics of Metals; member of the International Union of Pure and Applied Chemistry "Commission on Pure Metals and Their Protection"; Institute of Metals Award 1949 for outstanding research.

Besides those mentioned previously his interests include the vacuum microbalance and its use in the study of surface reactions, reaction of the newer metals, such as zirconium, titanium, tantalum, niobium and beryllium with oxygen, nitrogen and hydrogen, heater alloys, thermodynamics of high-temperature materials and the use of isotopes in the study of geochemical and geophysical processes.

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GALVESTON—MARCH 10-14

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***Pipeline Coating & Engineering* (68)**

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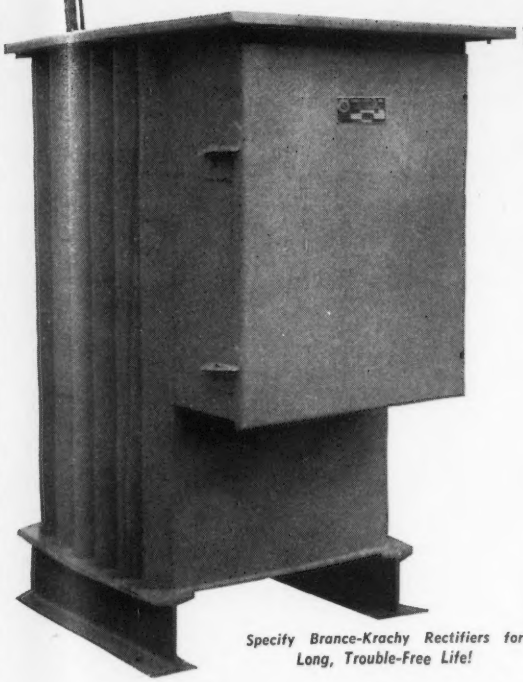

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Advance Information on the March 10-14, 1952 Galveston Conference

34 Papers in 9 Symposia Scheduled in Program

The advance program for the 1952 Galveston Conference March 10-14 lists 35 papers in nine symposia and also includes a motion picture followed by a discussion and two round table programs. An innovation this year will be the scheduling of technical committee meetings throughout the five days of the conference on a schedule designed to be non-conflicting with related symposia and other committee meetings.

The opening event of the technical program is the motion picture, "Corrosion in Action," supplied by the International Nickel Co., Inc. The two round table sessions are scheduled concurrently on the morning of Friday, March 14, last day of the conference.

Following is the advance technical program included in a mailing to association membership last month:

Monday—March 10

9:00 a.m. Registration all day.
Committee meetings all day.
Set up exhibits all day.

Tuesday—March 11

9:00 a.m. Committee meetings.
11:00 a.m. General Business Meeting.

ROBERT L. BULLOCK
Technical Program Chairman

2:30 p.m. **CORROSION PRINCIPLES SYMPOSIUM**
Motion Picture—"Corrosion in Action."
15 minute introduction by F. L. LaQue of The International Nickel Co., Inc., N. Y.
Round table discussion of motion picture.

6:00 p.m. Fellowship Hour and Barbecue, Texas style.
Registration all day.
Committee meetings all day.
Exhibition all day.

Wednesday—March 12

9:00 a.m. **OIL AND GAS PRODUCTION INDUSTRY SYMPOSIUM**
Stress Corrosion Cracking of Steels Under Sulfide Conditions by C. N. Bowers, W. J. McGuire and A. E. Weile, Gulf Oil Corp., Houston.
Cracking of High Strength Steels in Hydrogen Sulfide Solutions by J. P. Fraser and R. S. Treseder, Shell Development Co., Emeryville, Calif.
Field Experience with Cracking of High Strength Steels in Sour Gas and Oil Wells by NACE Technical Practices Committee 1-G—Sulfide Stress Corrosion.
Cathodic Embrittlement on Tubing Steels by F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.

(Continued on Page 24)

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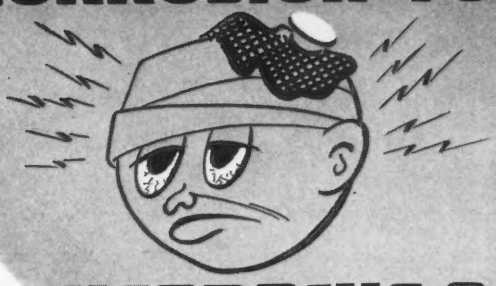

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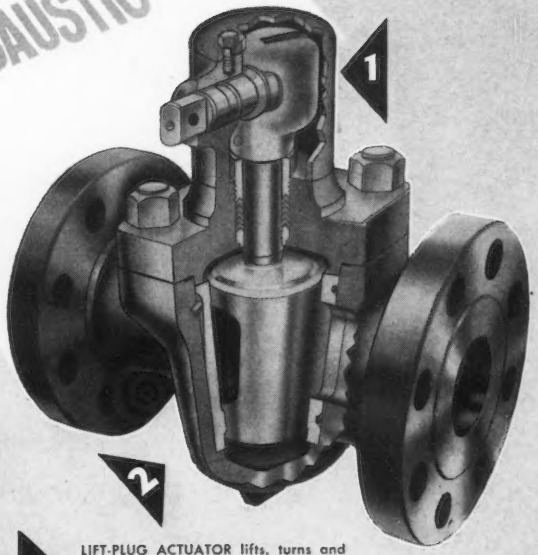

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Advance Information on the March 10-14, 1952 Galveston Conference

34 Papers—

(Continued from Page 22)

9:00 a.m. **CHEMICAL INDUSTRY SYMPOSIUM**

Corrosion by Sulfur and Sulfur Compounds at Elevated Temperatures by W. Z. Friend and E. N. Skinner, The International Nickel Co., Inc., New York.

Kel-F Application in Corrosive Systems by L. C. Rubin and W. O. Teeters, M. W. Kellogg Co., Jersey City, N. J.

Corrosion by Fluorine and Fluorine Compounds by Ralph Landau, Scientific Design Co., Inc., N. Y.

Effects of Mercury on Aluminum and Non-Ferrous Alloys by R. H. Brown, Aluminum Co. of America, New Kensington, Pa.

Polarographic Studies of Corrosion of Iron and Ferrous Alloys by Sulfur Dioxide by A. H. Gropp, University of Florida, Gainesville.

2:00 p.m. **OIL AND GAS INDUSTRY SYMPOSIUM**
(Continued)

Afternoon session—General Corrosion in Oil and Gas Production.

Laboratory Apparatus for Studying Oil Well Subsurface Corrosion Rates and Some Results by W. F. Rogers, P. J. Kalish and J. A. Rowe, Gulf Oil Corp., Houston.

Methods of Corrosion Testing in the Oil and Gas Production Industry by H. L. Bilhartz and H. E. Greenwell, Atlantic Refining Co., Dallas, Texas.

Corrosion Control in Gas Lift Wells by D. A. Shock and J. D. Sudbury, Continental Oil Co., Ponca City, Okla.

Sour Oil Well Corrosion by J. A. Caldwell, Humble Oil & Refining Co., Houston.

2:00 p.m. **REFINERY INDUSTRY SYMPOSIUM**

Some Observations of the Potentials of Stainless Steels in Flowing Sea Water by K. M. Huston, Armco Research Laboratories, Baltimore, Md., and R. B. Teel, International Nickel Co., Inc., Wrightsville Beach, N. C.

Economics of Industrial Maintenance Painting by Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia, Pa.

Corrosion Prevention of Distillation Process Equipment with Organic Inhibitors by George E. Purdy, Tretolite Co., St. Louis, Mo.

Graphitization of Carbon and Low Alloy Steel Plate Used for High Temperature Service by Joseph G. Althouse, Lukens, Steel Co., Coatesville, Pa.

Treatment of Recirculated Cooling Water by J. K. Rice, Cyrus Wm. Rice & Co., Inc., Pittsburgh, Pa.

Registration all day.

Exhibition all day.

Committee meetings all day.

Thursday—March 13

9:00 a.m. **ELECTRICAL AND COMMUNICATION INDUSTRY SYMPOSIUM**

An Improved Electronic Switch by V. B. Pike, Bell Telephone Laboratories, Murray Hill, N. J.

Isolation of Trolley-Bus Negative Return to Prevent Stray Current Corrosion by Stanley M. Seidman, Ohio Bell Telephone Co., Cleveland; Harvey E. Nerhood and Richard H. Travers, Ohio Edison Co., Akron, and Louis Harvath, Ohio Bell Telephone Co., Cleveland.

A Laboratory Method for Evaluating Steam Condensate Return Line Corrosion Inhibitors by Harold I. Patzelt, National Aluminate Corp., Chicago.

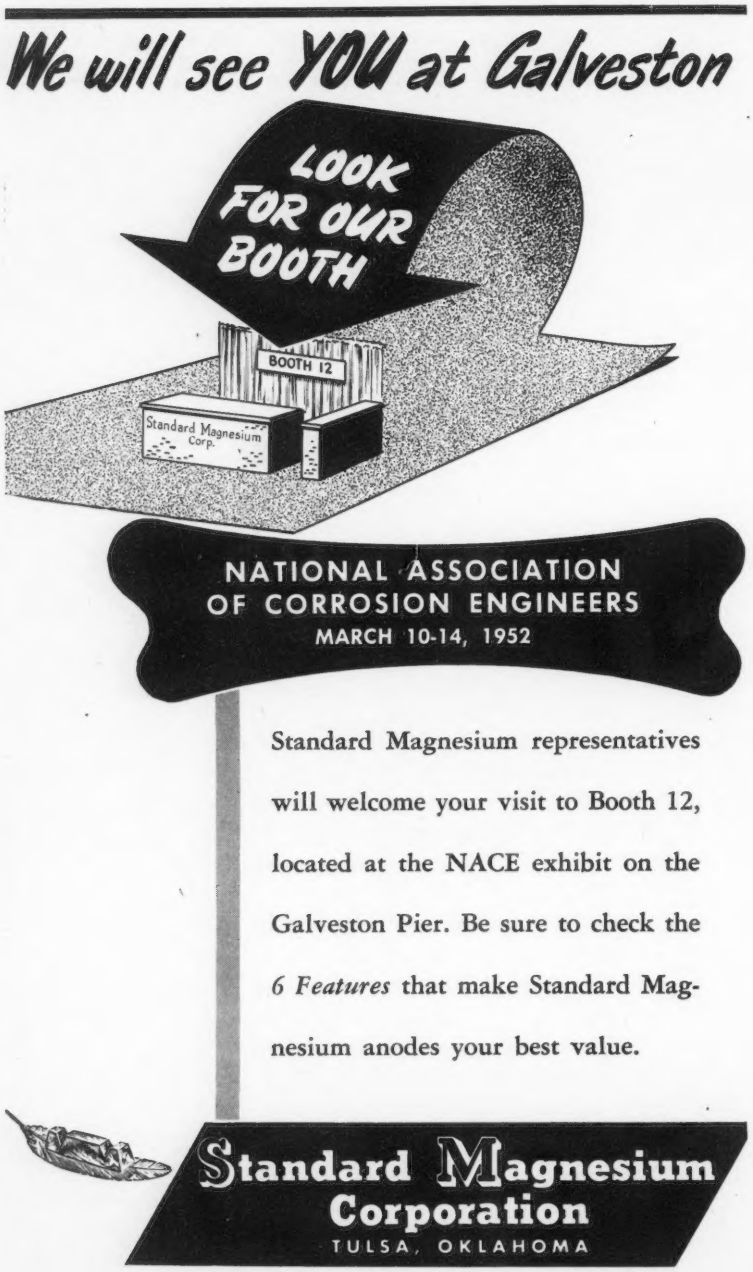
Rectifiers Used for Cathodic Protection Systems by T. J. Maitland, American Telephone and Telegraph Co., N. Y.

9:00 a.m. **PROTECTIVE COATING INDUSTRY SYMPOSIUM**

Protection of Off-Shore Production Equipment by H. L. Bilhartz, Atlantic Refining Co., Dallas.

Coating Experiences with Cathodic Protection—Underwater by Ray Devoluy, C. A. Woolsey Paint Co., New York City.

(Continued on Page 28)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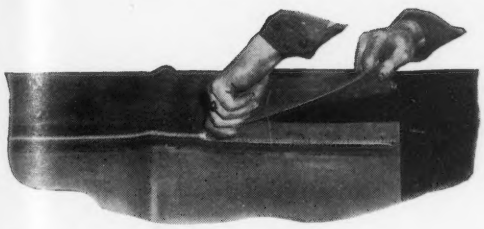
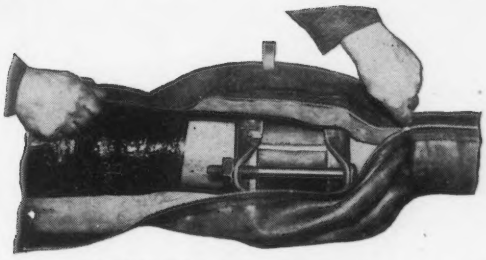


Dresser ZIPCOAT for welded joints zips over weld area, fits closely to the pipe. 30″ lengths.



Dresser ZIPCOAT for couplings is easy to install over joint and pipe ends—all in one quick operation. Has bleeder valve to vent air during backfilling.

Dresser ZIPCOAT for insulating joints is made like the ZIPCOAT for welds, but in ten-foot lengths. Installing one on each side of an insulating joint that's protected with a ZIPCOAT for couplings gives ultimate protection. Eliminates costly boxing and filling with dope. Immediate trench backfill saves time.

NEW DRESSER ZIPCOATS* GIVE SURE PROTECTION, SUPERLATIVE DIELECTRIC STRENGTH

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And look at the hazards you avoid: there's no flame; no heating, hauling or messy application of hot stuff; no danger from fumes or burns.

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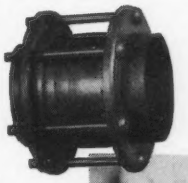
Write today for descriptive material and price list.

*Every ZIPCOAT complete with anaerobic microbiological corrosion inhibitor and cold sealing compound. ZIPCOAT is a trade mark of Dresser Manufacturing Division.



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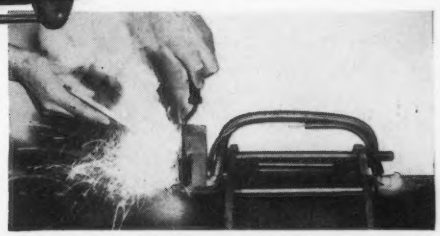
Dresser Style 39 Insulating Couplings with new plastic gaskets insulate effectively and are the simplest insulating type joint to install. Sizes ¾″ to 30″ and up.



New Dresser Bonding Method saves up to 50% of cost; materials preformed

Fast bonding, giving low resistance with *pre*formed Dresser Bond and 5-second chemical welding method. Needs no special skill, no bulky equipment. Makes homogeneous weld area, eliminates surface contact variables. Compact kit of 50 *pre*formed bonds includes all materials needed for installing.

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HERE'S BIG NEWS in vinyl coatings

- a new and unique primer
- virtually eliminates surface preparation
- dries hard in a matter of minutes
- can be used with any type finish—particularly vinyls

318c

TYGO

TYGORUST— the "no prep" primer for wet or dry rusted steel, wood or concrete

Corrosion engineers! Here's the biggest development in vinyl coatings in recent years — TYGORUST — a truly different primer that not only adheres to rusted steel, but also dries in minutes and can be successfully overcoated with any type of finish.

The result of years of formulation and testing, TYGORUST has been specifically developed to overcome the two major limitations of vinyl based protective coatings — the need for highly specialized primers and the need for careful surface preparation. While everyone concerned with corrosion has long acknowledged the outstanding chemical resistance of Tygon and other vinyl coatings, their use has been limited to only those jobs which warranted the extra pre-treatment needed — to only those jobs of protecting against chemical attack which no other coatings could handle.

In order to make the superior chemical resistance of vinyl finishes more generally useful, a primer has been needed that would adhere to steel in practically any condition; that would dry hard in a relatively short time; and, that would provide a good base for the satisfactory adhesion of topcoats. TYGORUST IS THE ANSWER TO THE PROBLEM! TYGORUST MAKES VINYL COATINGS AVAILABLE FOR THE FIRST TIME FOR GENERAL MAINTENANCE USE.

Here's what TYGORUST does! It brushes easily — sprays beautifully — levels quickly — dries hard in minutes — really bonds — and can be recoated, without lifting, with vinyl, introcellulose, asphalt, alkyd or oleoresinous coatings. TYGORUST can be brushed or sprayed on steel, clean or rusted — dry or damp, with equal ease. Recoating is possible in as little as ten minutes. Adhesion is excellent in all cases.

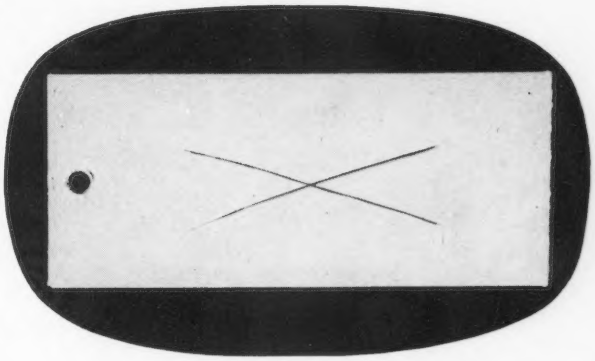
Under exaggerated test conditions, TYGORUST has been brushed on dripping wet, rusted steel with completely satisfactory adhesion and only slightly prolonged drying and recoating. In other tests, badly rusted iron and steel have been successfully primed, without wire brushing. Virtually no preparation other than removing loose, flaking scale and oil or grease is required.

In addition to its strong adhesion and ease of application to steel, TYGORUST can also be applied to concrete, unpainted wood, and previously painted surfaces (bituminous coating excepted) with excellent results. Furthermore, TYGORUST is rust-inhibitive and displays good chemical resistance.

Indication of the rust-inhibitive properties of this new primer can be found in the results of salt spray tests wherein previously rusted panels were primed with TYGORUST and top-coated with TYGON "Series K" Paint. At the end of 120 hours in the spray cabinet (see photo), there was no evidence of rust creepage along the scorings.

But, don't take our word for it — test TYGORUST yourself! Get a trial quantity, today — give TYGORUST the roughest test you can — and, actually see how well it works.

Don't forget, either, to see TYGORUST at the forthcoming NACE Exhibition — Booths 78 and 79.



Actual photograph of previously rusted steel panel, primed with TYGORUST and top-coated with TYGON "Series K" Paint, after 120 hours' exposure in salt spray cabinet. Note complete lack of rust creepage.

The U. S. STONEWARE Co., Plastics and Synthetic Division, Akron 9, Ohio

RUST

Advance Information on the March 10-14, 1952 Galveston Conference

34 Papers—

(Continued from Page 24)

Values of Surface Preparation and/or Pretreatment for Use in Conjunction with Various Outstanding Paint Systems in Industrial and Marine Atmosphere by J. C. Hudson and F. Fancutt, British Iron and Steel Research Association, London, England.

Metallizing Economics in Modern Industry Surface Application Studies by R. J. McWaters, Metallizing Engineering Co., Inc., Long Island, N. Y.

2:00 p.m. **OIL AND GAS TRANSPORTATION AND STORAGE INDUSTRY SYMPOSIUM**

Aluminum Alloys for Offshore Pipe Lines by E. T. Wanderer, Aluminum Co. of America, New Kensington, Pa.

Electrical Measurements Applied to Corrosion Investigations by W. R. Schneider, Pacific Gas & Electric Co., Emeryville, Calif., and David Hendrickson, East Bay Municipal Utility District, Oakland, Calif.

Cathodic Protection of Tank Bottoms by S. P. Ewing, Carter Oil Co., Tulsa, Okla.

The Role of Oxygen in Corrosion and Cathodic Protection by R. B. Comeaux, Humble Oil & Refining Co., Baytown, Texas.

2:00 p.m. **MARINE INDUSTRY SYMPOSIUM**

The Use of Magnesium Anodes in Cathodic Protection by H. A. Humble, Dow Chemical Co., Midland, Mich.

Gasoline Resistant Tank Coatings by Walter Cranmer, Philadelphia Naval Shipyard, Philadelphia, Pa.

Corrosion Resistant Characteristics of Iron Modified 90/10 Cupro-Nickel Alloy by W. C. Stewart, Engineering Experiment Station, Annapolis, Md., and F. L. LaQue, The International Nickel Co., Inc., N. Y.

Studies on the Relationship Between the Profile Depth of Grit Blasted Surfaces and the Coating Thickness by Max Kronstein, College of Engineering, New York University.

Registration all day.
Exhibition all day.
Committee meetings all day.

Friday—March 14

9:00 a.m. **PIPE LINE AND UNDERGROUND CORROSION ROUND TABLE**

Chairman, Kirk H. Logan, Cast Iron Pipe Research Institute, Washington, D. C., and Co-Chairman, O. C. Mudd, Shell Pipe Line Corp., Houston.

9:00 a.m. **GENERAL CORROSION ROUND TABLE**

Chairman, R. B. Hoxeng, U. S. Steel Co., Pittsburgh, Pa., and Co-Chairman, Frank L. Whitney, Monsanto Chemical Co., St. Louis, Mo.

Exhibition, forenoon only.

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A Metallurgist or Metallurgical Engineer to work on Chemical Plant corrosion. He will be in charge of a Metallurgical and Photographic Laboratory and will be responsible for corrosion and material testing and for specifications for new constructions and processes. Experience desired but not necessary. Salary commensurate with training and experience. Contact Personnel Department, Celanese Corporation of America, Chemcel Plant, Box 148, Bishop, Texas.

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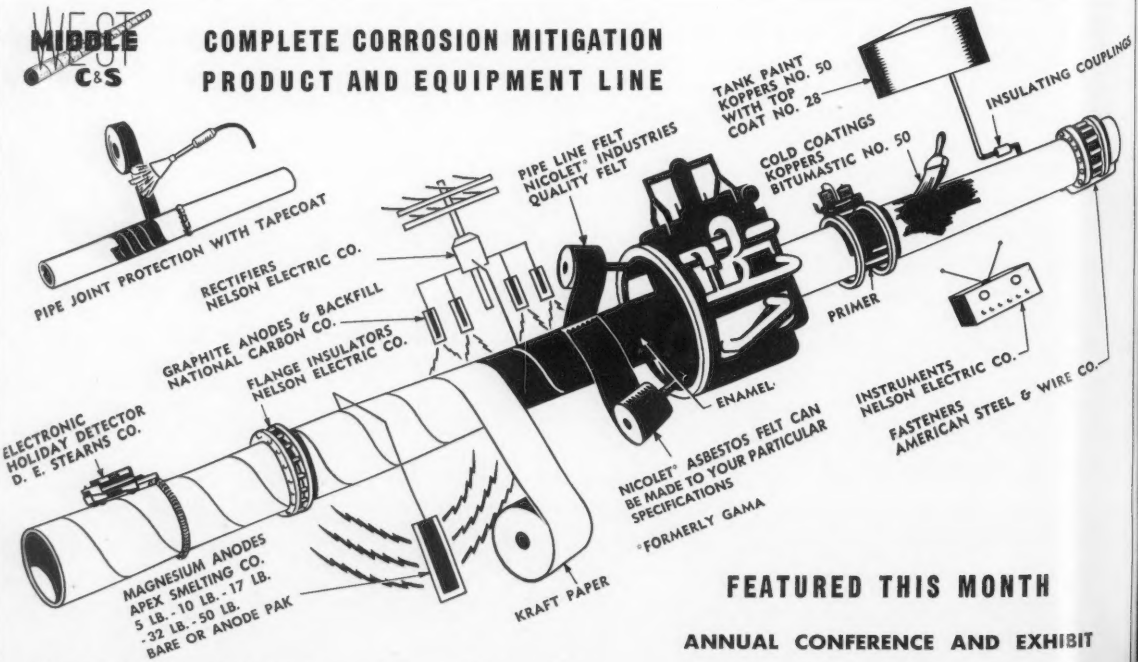
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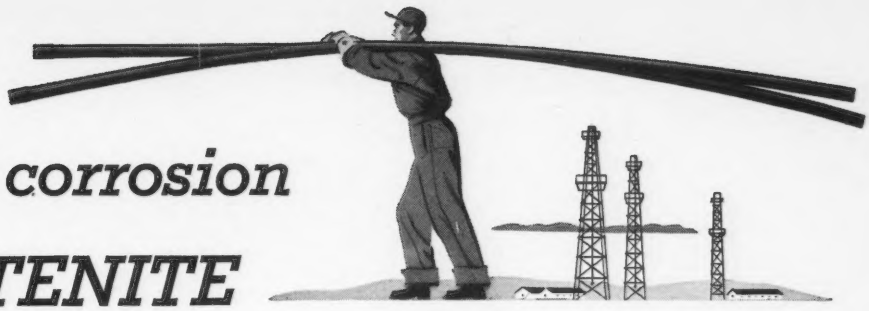

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Many miles of Tenite pipe are now in service in the oil fields carrying sour crude oil and salt water.

The smooth-walled Tenite pipe weighs only a fraction as much as steel pipe and requires no special equipment to install — one man can easily shoulder two 20-foot lengths. Slip-sleeve and molded Tenite couplings assemble the lengths speedily and permanently.

Tough, noncorrodible Tenite pipe has high impact strength, weathers well, is flexible enough to follow earth contour and to withstand expansion caused by ice formation.

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For further information about Tenite pipe, write Tennessee Eastman Company, Division of Eastman Kodak Company, Kingsport, Tennessee.

• *Oil field tubing extruded by Carlon Products Corporation, Cleveland, Ohio, and distributed by Green Contracting and Engineering Company, Wichita, Kansas.*

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Information regarding Tenite is also obtainable through representatives located in Chicago, Cleveland, Dayton, Detroit, Leominster (Mass.), Los Angeles, New York, Portland (Ore.), Rochester (N. Y.), St. Louis, San Francisco, and Seattle; and elsewhere throughout the world from Eastman Kodak Company affiliates and distributors.

Advance Information on the March 10-14, 1952 Galveston Conference

Stress Corrosion Cracking to Be Featured in Oil and Gas Symposium

The Oil and Gas Production Industry Symposium and the Oil and Gas Industry Symposium are two parts of the same general topic. The symposium to be held beginning at 9 a.m. Wednesday, March 12, will be devoted to stress corrosion cracking under sulfide conditions. This subject, which is of growing importance in the oil industry as a consequence of the greater volumes of sour crudes now being produced, will be covered by four papers.

Of these, one by J. P. Fraser and R. S. Treseder, "Cracking of High Strength Steels in Hydrogen Sulfide Solutions," gives laboratory data relating to the spontaneous cracking and embrittlement of steel alloys in sour gas condensate wells. A mechanism involving stress corrosion cracking and hydrogen embrittlement is proposed to explain the cracking. Remedial measures also are discussed.

F. A. Prange's paper, "Cathodic Embrittlement on Tubing Steels," tells of cathodic tests made on a number of alloys with good properties for use in deep corrosive wells.

A presentation of field experiences with cracking of high strength steels in sulfide environments will be made by Technical Practices Committee 1-G on Sulfide Stress Corrosion.

General Corrosion in Oil and Gas Production To Be Covered March 12

General corrosion in oil and gas production will be the topic of the Oil and Gas Industry Symposium beginning at 2 p.m. Wednesday, March 12. This is the second half of the oil and gas industry corrosion technical material prepared for the conference. This symposium, consisting of four papers, deals principally with corrosion control and testing in wells.

"Laboratory Apparatus for Studying Oil Well Subsurface Corrosion Rates and Some Results," by W. F. Rogers, J. A. Rowe and P. J. Kalish of Gulf Oil Corp., will give details about an apparatus constructed for studying the corrosion rates of oil well brines under conditions simulating those at the bottoms of wells. The effects of carbon dioxide or hydrogen sulfide are explored, a method of testing inhibitors is described and data presented showing mercaptans to act as inhibitors of corrosion.

"Methods of Corrosion Testing in the Oil and Gas Producing Industry," by H. L. Bilhartz and H. E. Greenwell of Atlantic Refining Co., Dallas, gives detailed descriptions of some test methods useful in evaluating corrosion control methods in oil and gas producing equipment. Laboratory, field and combined laboratory-field tests are described.

The coupon testing technique used by one company is described. An estimate of the cost of coupon studies is included.

"Corrosion Control in Gas Lift Wells," by D. A. Shock and J. D. Sudbury of Continental Oil Co., Ponca City, Okla., describes methods used to determine the causes of corrosion in gas lift wells in South Texas. Finding these wells to have a considerable water column in the annular space, the authors conclude an inhibitor to be effective must mix with the water and fall to the bottom. Oil soluble and emulsifiable inhibitors, they state, were blown through the gas lift valves and did not reach the bottom of the well.

"Sour Oil Well Corrosion," by J. A. Caldwell, Humble Oil & Refining Co., Houston, chairman of Technical Practice Committee 1-D, discusses the work of this committee in which the committee learned that 3618 wells out of 8215 sour-crude wells in Arkansas, West Texas and Kansas were economically affected by corrosion. Cost and effectiveness of remedial measures is discussed.

•

Technical papers presented at national meetings of NACE are usually published in Corrosion after review and approval by the association's editorial review committee and the editor of Corrosion.

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SIMPLE TEST

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You are invited to visit Monsanto's Exhibit, Booths 85 and 86, Pleasure Pier, Galveston, Texas, during the NACE Annual Conference, March 10-14.

(1) Control **(2) 3 ppm Santolene C** **(3) 7½ ppm Santolene C**

You don't need a laboratory to make this simple test to prove that Monsanto Santolene C can solve your corrosion problems. It may point the way to saving millions lost through corrosion damage to tanks, tankers, pipelines and refinery equipment.

Fill three bottles with 75 grams gasoline, kerosene or other light petroleum product. Add 2 cc water to each bottle. Use one as the control. Add 3 ppm and 7½ ppm of Santolene C to the other bottles. Drop a strip of clean steel into each of the bottles. Notice how soon corrosion starts on the metal in the uninhibited gasoline and how bright the other test strips remain.

This test demonstrates the effectiveness of Santolene C in the control of corrosion under static conditions. Tests of corrosion control with Santolene C under dynamic conditions have been equally spectacular.

Minute quantities of Santolene C, added to gasoline, kerosene and other light petroleum products, effectively control corrosion. This has been proved in actual use by major oil refiners.

If you would like to test Santolene C as suggested here, we'll be glad to send you a sample of the product. MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second St., St. Louis 4, Missouri.

SANTOLENE C

Santolene: Reg. U.S. Pat. Off.

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CHEMICALS AND PLASTICS

SERVING INDUSTRY... WHICH SERVES MANKIND

Advance Information on the March 10-14, 1952 Galveston Conference

Chemical Industry Symposium Has Five Papers Scheduled

A variety of corrosive conditions will be discussed during the Chemical Industry Symposium. Five papers are scheduled.

"Corrosion by Sulfur and Sulfur Compounds at Elevated Temperatures," by E. N. Skinner and W. Z. Friend of The International Nickel Co., Inc., New York, is an attempt to evaluate factors that influence corrosive attack on heat resisting alloys when exposed to hot sulfur-containing atmospheres. The authors say in general the attack is less severe under conditions which permit simultaneous formation of an oxide film.

"Effects of Mercury on Aluminum and Non-Ferrous Alloys," by M. H. Brown, W. W. Binger and R. H. Brown of Aluminum Research Laboratories reveals how severe corrosion in non-ferrous alloy equipment has been traced in some cases to mercury. A series of studies was initiated to determine the role of mercury in corrosion and the concentration levels that might cause serious attack. The results of the laboratory work and service experience show that contamination by mercury or its compounds constitutes a serious corrosion menace.

"Kel-F Applications in Corrosive Systems," by L. C. Rubin and W. O. Teeters of the M. W. Kellogg Co, Jersey City, describes the properties and uses of thermoplastic fluorochlorocarbons derived from chlorofluoroethylene and available under the trade name "Kel-F." Data on the vapor permeability of films prepared from dispersions are given.

Other papers in the symposium are "Corrosion by Fluorine and Fluorine Compounds," by Ralph Landau, Scientific Design Co., New York, and "Polarographic Studies of Corrosion of Iron and Ferrous Alloys by Sulfur Dioxide," by A. H. Gropp, University of Florida, Gainesville.

Two of Refinery Symposium Papers Deal With Metallurgy

Two of the five papers in the Refinery Industry Symposium deal with metallurgy, one with refinery painting and two with inhibitors. Of the latter one deals with distillation process equipment and the other with recirculated cooling water.

"Some Observations of the Potentials of Stainless Steels in Flowing Sea Water," by K. M. Huston and R. B. Teel, The International Nickel Co., Inc., Wilmington, N. C., reports on the sea water potentials of nine standard and three new grades of stainless steels. Effect of heat treatment and crevice corrosion on the EMF potentials are discussed. Testing equipment is described.

"Graphitization of Carbon and Low Alloy Steel Plate Used for High Temperature Service," by Joseph G. Althouse, Lukens Steel Co., describes previous investigations into graphitization failures and postulates that plate can be produced sufficiently stable to avoid dangerous graphitization at high temperatures, high temperature or high stress.

"Economics of Industrial Maintenance Painting," by Robert R. Pierce, Pennsylvania Salt Manufacturing Co., Philadelphia. This paper describes an investigation into the economics of protective coatings in chemical-industrial atmospheres.

"Corrosion Prevention of Distillation Process Equipment With Organic Inhibitors," by George E. Purdy, Tretolite Co., St. Louis, Mo., tells of the film forming characteristics of high molecular weight organic corrosion preventives. It is claimed these preventives lessen requirements for strict pH control. They also have a detergent action, preventing salt and solid deposition on heat exchangers.

"Treatment of Recirculated Cooling Water," by J. K. Rice of Cyrus Wm. Rice & Co., Inc., reviews published work since 1940 on treatment of recirculated cooling water. Results indicate the level of knowledge concerning variables is at about the same level as that 25 years ago in the internal treatment of boilers.

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March 10-14, 1952

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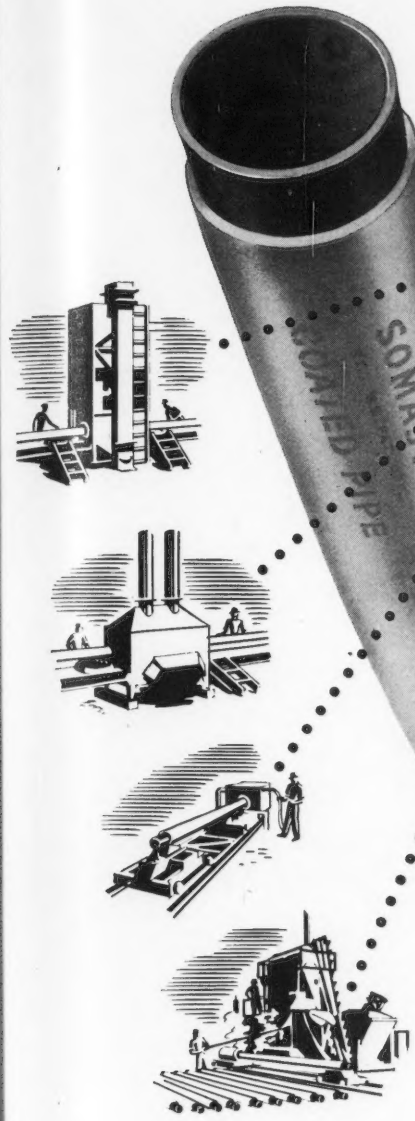

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Advance Information on the March 10-14, 1952 Galveston Conference

Problems Encountered With Trolley-Bus Negative Return Given

The corrosion problems resulting from continued use of abandoned street railway tracks as a negative return for trolley bus transmission systems are described in a paper, "Isolation of Trolley-Bus Negative Return to Prevent Stray Current Corrosion," by Stanley M. Seidman, Ohio Bell Telephone Co., Cleveland; Harvey E. Nerhood and H. Travers, Ohio Edison Co., Akron, Ohio, and Louis Horvath, Ohio Bell Telephone Co., Cleveland. This is one of four papers in the Electrical and Communications Industry Symposium to be held beginning at 9 a.m. Thursday, March 13.

The problem of corrosion is presented from the viewpoints of two utilities, the Ohio Edison Co. and the Ohio Bell Telephone Co., with an exposition of conditions before and during the use of street rails as a negative return in Akron and Youngstown, Ohio. The problems arising from this use were such the rail return was abandoned and the negative return was isolated from the ground.

Laboratory testing of steam condensate corrosion is described by Harold I. Patzelt of National Aluminate Corp., Chicago, in his paper, "A Laboratory Method for Evaluating Steam Condensate Return Line Corrosion Inhibitors." Mr. Patzelt outlines an experimental arrangement whereby a synthetic condensate is produced with controlled quantities of free carbon dioxide and various inhibitors added. Results from these tests are evaluated by examination of steel test coupons.

Other papers in this symposium are "An Improved Electronic Switch," by V. B. Pike, Bell Telephone Laboratories, Murray Hill, N. J., and "Rectifiers Used for Cathodic Protection Systems," by T. J. Maitland, American Telephone and Telegraph Co., New York.

CHARLES E. GRIBBLE, JR.
Local Arrangements Chairman

Local Arrangements Committees Complete

Chairmen and co-chairmen in charge of local arrangements for the Galveston Conference of the National Association of Corrosion Engineers, March 10-14, 1952, have been named as follows by Charles G. Gribble, Jr., local arrangements chairman:

Printing Committee: Oliver Osborn, Dow Chemical Co., Freeport, chairman; J. B. Chatelain, Freeport Sulphur Co., Freeport, co-chairman.

Meeting Rooms Committee: Jack Battle, Humble Oil & Refining Co., chairman; Gordon Doremus, Cathodic Protection Service, co-chairman.

Registration Committee: A. L. Stegner, Tennessee Gas Transmission Co., chairman; Herschel Wood, Lebanon Steel Foundry, co-chairman.

Entertainment Committee: W. F. Oxford, Jr., Sun Oil Co., Beaumont, chairman; W. H. Stewart, Sun Oil Co., Beaumont, co-chairman.

Ladies' Entertainment Committee: W. H. Waring, Johns-Manville Co., chairman; Charles D. Brown, Aluminum Co. of America, co-chairman.

Housing Committee: P. E. Darling, Pan American Refining Co., Texas City, chairman; Walter Janssen, Pan American Refining Co., Texas City, co-chairman.

Metallurgy and Anodes Are Protective Coatings Symposium's Topics

The corrosion resistant characteristics of an iron modified 90/10 cupro-nickel alloy, gasoline resistant tank coatings, cathodic protection and a paper on the relationship between profile depth of a grit blasted surface and coating thickness are covered in papers to be given during the Marine Industry Symposium which begins at 2 p.m. Thursday, March 13.

"Gasoline Resistant Tank Coatings," by W. W. Cranmer, Industrial Test Laboratory, Philadelphia Naval Shipyard describes certain coatings used successfully in limiting corrosion in interiors of gasoline carrying tankers and railroad tank cars. Tests underway are described and a discussion of the problem of coating underground concrete gasoline storage tanks is covered.

"Studies on the Relationship Between the Profile Depth of Grit-Blasted Surfaces and Coating Thickness," by Max Kronstein of the College of Engineering, New York University, gives correlations between the effect of this kind of surface preparation and various coating thicknesses to determine the minimum economical thickness.

Other papers in the symposium are "The Use of Magnesium Anodes in Cathodic Protection," by H. A. Humble, Dow Chemical Co., Midland, Mich. and "Corrosion Resistant Characteristics of Iron Modified 90/10 Cupro-Nickel Alloy," by W. C. Stewart, Engineering Experiment Station, Annapolis, Md. and F. L. LaQue, The International Nickel Co., Inc., New York.

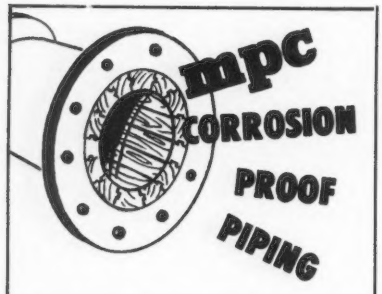
Advantages of Aluminum Pipe Lines in Salt Water to Be Given

The use of aluminum as a material for pipe lines laid in salt water, a new development in cathodic protection using magnesium, and electrical measurements in corrosion investigations are three of the topics to be presented during the Oil and Gas Transportation and Storage Industry Symposium which begins at 2 p.m. Thursday, March 13.

"Aluminum Alloys for Offshore Pipe Lines," by E. T. Wanderer of Aluminum Co. of America, describes 20 months' experience with a partially unprotected 4-inch aluminum pipe line extending 3500 feet into Matagorda Bay, Texas. Techniques recommended for welding and laying the line are discussed.

"Electrical Measurements Applied to Corrosion Investigations," by W. R. Schneider, Pacific Gas and Electric Co., Emeryville, Calif., and David Hendrickson, East Bay Municipal District, Oakland, Calif., deals with electrical measurement used by Pacific Gas and Electric Co. on gas transmission lines running from Arizona to Northern California. Methods of investigation used by East

(Continued on Page 36)



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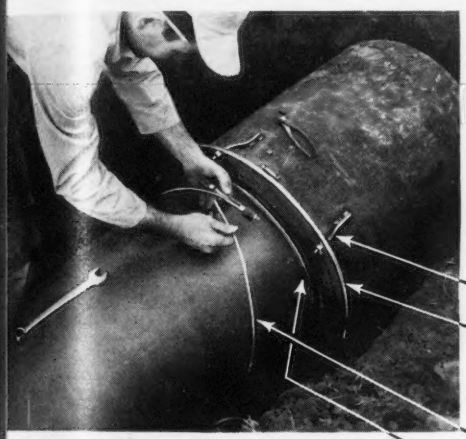
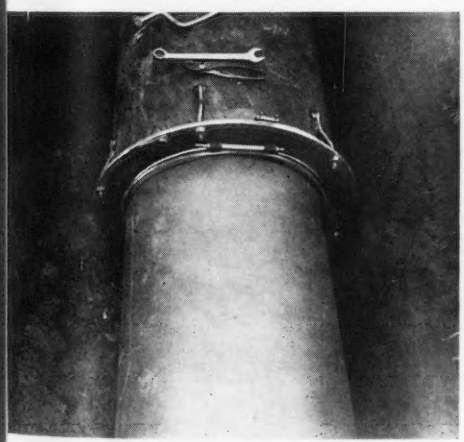


Assembling cable with rubber-covered union for clamping gasket lip to pipe.



THE COMPLETED INSTALLATION
Note that galvanized cable and union are insulated from pressure flange and from pipe.

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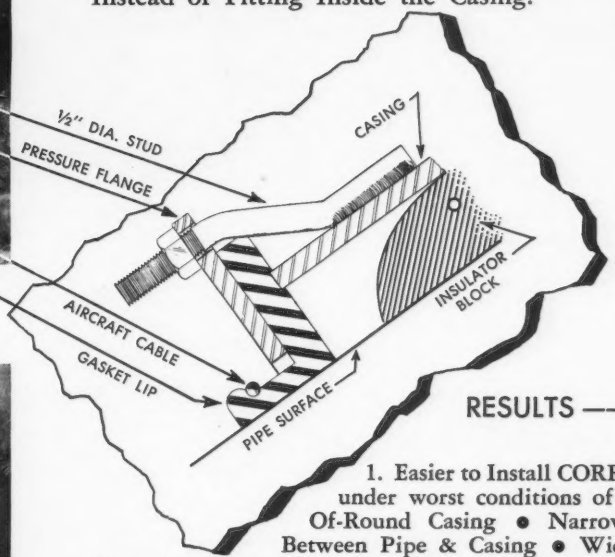

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Advance Information on the March 10-14, 1952 Galveston Conference

Four Major Topics Are Scheduled for Marine Symposium

Salt water environments, coating and cathodic protection, values of surface preparation and economics of metallizing are the four topics of papers to be given in the Protective Coating Industry Symposium. The symposium will begin at 9 am Thursday, March 13.

The four papers scheduled are:

"Protection of Off-Shore Production Equipment," by H. L. Bilhartz, Atlantic Refining Co., Dallas.

"Coating Experiences with Cathodic Protection—Underwater," by Ray Devoluy, C. A. Woolsey Paint Company, New York.

"Values of Surface Preparation and/or Pretreatment for Use in Conjunction with Various Outstanding Paint Systems in Industrial and Marine Atmospheres," by J. C. Hudson and F. Fancutt, British Iron and Steel Research Association, London, England.

"Metallizing Economics in Modern Industrial Surface Application Studies," by R. J. McWaters, Metallizing Engineering Co., Inc., Long Island, N. Y.

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Technical material on corrosion will be considered by the NACE Editorial Review Committee from any source. Information on requirements of the association as to form of papers may be obtained on application to Central Office, Houston.

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Exhibits by more than 77 firms will occupy exhibit space on Galveston's Pleasure Pier, which is located on pilings over the Gulf of Mexico. Entrance to the pier is on the Galveston Sea Wall, and only a short distance from the Buccaneer Hotel and Galvez Hotel.

Exhibit space is so arranged that persons attending symposia in the Marine Room of the pier, which is located at the seaward end, will traverse the fronts of all booths.

Advantages of—

(Continued from Page 34)

Bay Municipal Utility District on large aqueducts also will be detailed.

"The Role of Oxidation in Corrosion and Cathodic Protection," by R. V. Comeaux, Humble Oil & Refining Co., Baytown, Texas, outlines theoretical considerations involved in diffusion of oxygen as part of corrosion phenomena.

The other paper in the symposium is "Cathodic Protection of Tank Bottoms," by S. R. Ewing, Carter Oil Co., Tulsa, Okla.

•

An index covering all technical material published in Corrosion for the years 1945-50 inclusive was published in the December, 1950, issue. Copies of the issue are available. The indices may be extracted and used separately if desired.

All NACE regions cooperated in securing technical papers for the 1952 Galveston Conference. R. L. Bullock, technical program chairman, early enlisted the assistance of program co-chairmen in each region and the cooperation of technical practices committees in securing papers.

Following are the names of the persons responsible for the technical program:

George E. Best, Mutual Chemical Co., Baltimore, is technical program co-chairman responsible for the Electrical and Communications Industry, Refinery Industry and Marine Industry Symposia.

Officials of these symposia are:

Electrical and Communications Industry—M. D. Fletcher, Illinois Bell Telephone Co., Chicago, chairman; J. S. Vetlik, Northern Indiana Public Service, Hammond, Indiana, co-chairman.

Refinery Industry—J. K. Deichler, The Atlantic Refining Co., Philadelphia, Pa., chairman; D. L. Burns, Gulf Oil Corp., Port Arthur, Texas, co-chairman.

Marine Industry—Allen L. Alexander, Naval Research Laboratory, Washington, D. C., chairman; Charles M. Jackson, Devoe & Reynolds Co., Newark, N. J., co-chairman.

F. L. Whitney, Monsanto Chemical Co., St. Louis, is technical program co-chairman for the Chemical Industry and Protective Coatings Industry Symposia.

Officials of these symposia are:

Chemical Industry—P. J. Gegner, Columbia-Southern Chemical Corp., Barberton, Ohio.

Protective Coatings Industry—A. J. Liebman, Dravo Corp., Pittsburgh, chairman; L. L. Whiteneck, Long Beach Harbor Dept., Long Beach, Calif., co-chairman.

Derk Holsteyn, Shell Oil Co., Houston, is technical program co-chairman of the Oil and Gas Production Industry and Oil and Gas Industry (General Corrosion in Oil and Gas Production) symposia.

Officials of these symposia are:

Oil and Gas Production Industry—H. E. Waldrip, Gulf Oil Corp., Houston, chairman; H. L. Bilhartz, Atlantic Refining Co., Dallas, co-chairman.

Oil and Gas Transportation and Storage Industry—L. G. Sharpe, Humble Pipe Line Co., Houston, chairman; O. C. Roddey, Interstate Natural Gas Co., Inc., Monroe, La., co-chairman.

R. A. Davis, Chicago Bridge and Iron Co., Birmingham, Alabama, was co-chairman for South East Region and David Hendrickson, East Bay Municipal District, Oakland, Calif., was co-chairman for Western Region. No specific responsibility was assigned these two officials, but they assisted in securing papers from their respective areas.

The Corrosion Principles Symposium, scheduled first, is under the supervision of Norman Hackerman, University of Texas, Austin.

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Pages in the Corrosion Abstract Section of Corrosion are numbered serially in each volume so they may be bound by years with the annual index.

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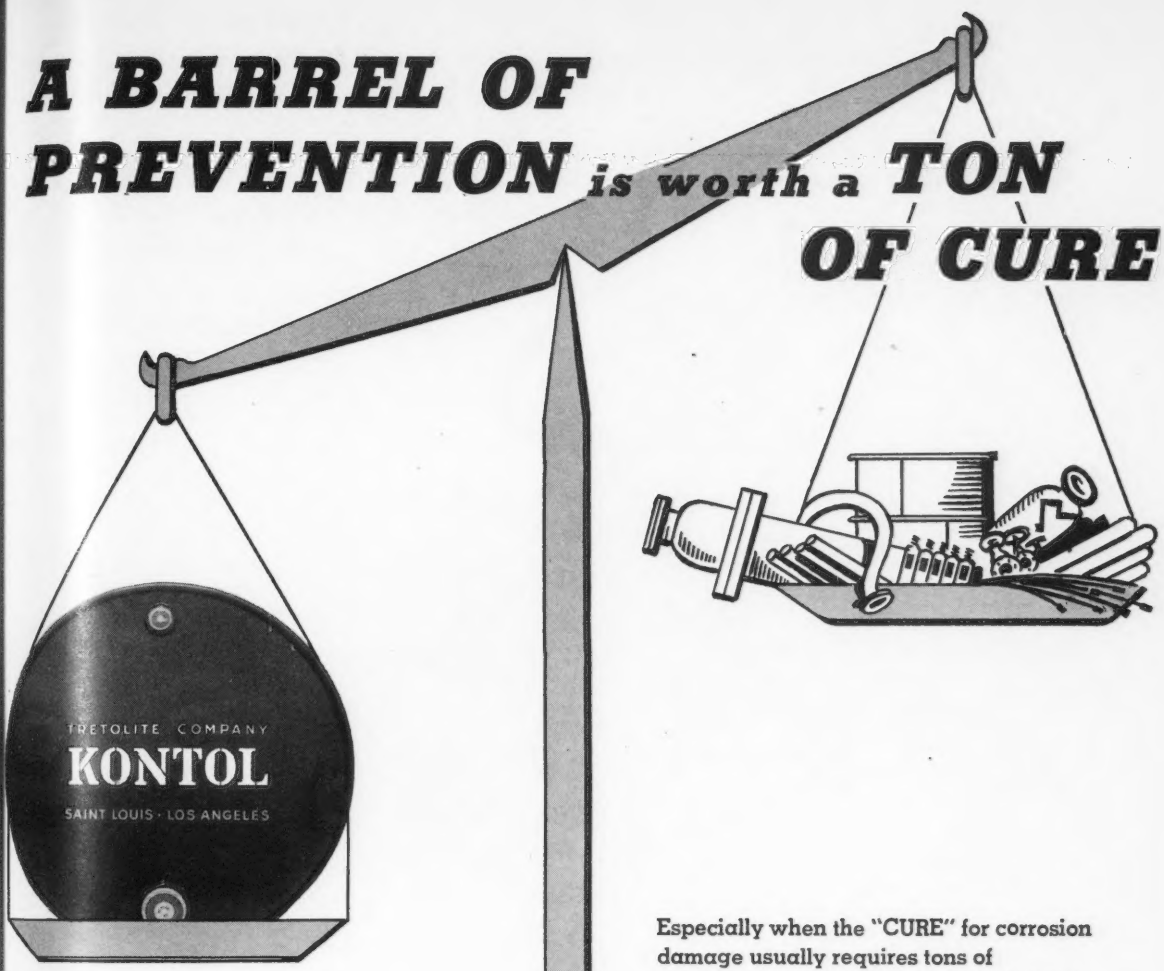

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Registration Planned At Three Places

Places for registration will be provided at three points, according to present plans. There will be registration provisions at both the Buccaneer and Galvez Hotels and on the Galveston Pleasure Pier.

Official registration will begin at 9 a.m. Monday, March 10 and will continue through Tuesday.

Plans for Collection Of Discussions Made

Remarks and discussions about technical papers presented at the conference will be handled in about the same way as in recent conferences. Forms will be supplied on which those who have comments may write their questions or comments. These are collected and sent to authors of papers for replies, and the remarks and replies printed, if possible, at the same time the paper is published in CORROSION.

The association will consider for publication comments on technical material presented at its meetings or published by it at any time.

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Both decorating and cartage for the Galveston Exhibit will be handled by Southwestern Decorators, 6225 St. Augustine Street, Houston, Texas.

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For a handling charge of $5 the National Association of Corrosion Engineers will ship postage paid to authors of technical material published in CORROSION, not earlier than six months after publication, printing plates used for figures in articles, NACE undertakes to ship such printing plates as are available, without warranty as to their condition or completeness. Those who wish to take advantage of this offer are asked to submit a request in writing, giving the issue in which the article in question was published, full address to which plates are to be shipped and billing information to:

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919 Milam Building,
Houston 2, Texas

Corrosion Abstracts

CORROSION CONTROL — PROTECTS INDUSTRY — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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1. GENERAL

1.1 Miscellaneous

1.1

Report on Round Table Discussion on General Corrosion Problems. F. L. LaQue. *Corrosion*, **6**, No. 10, 327-331 (1950) Oct.

Covers session held at NACE conference, St. Louis, Apr. 4-7, 1950.—BLR.

1.1

The Iron Curtain in Metallurgical Literature. Henry Brutcher. *Metal Progress*, **58**, 331-333+ (1950) Sept.

A well-known translator of foreign metallurgical literature reviews the appearance, disappearance and present status of Russian metallurgical and scientific journals over the past 25-30 years. Shows how use of non-Russian titles and abstracts in the Russian journals varies with the political situation. Points out that Soviet statistics, when given at all, have sometimes been too low, sometimes too high. Tells sad story of an attempt to secure technical literature directly from a Russian scientist.—BLR.

1.1

I & EC Fact Cards. *Ind. and Eng. Chem.* **42**, 87A-98A (1950) Sept.

In new department printed on card stock, paid advertisements are presented in a consistent format describing a large number of physical and chemical characteristics of industrially significant chemicals. Both format and content are designed specifically for the reader who will use such a feature as a reference data file for technical grades of industrially available chemicals. The front of

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Persons who wish to secure copies of articles when original sources are unavailable, may apply directly to any of the above for copies. Full reference information should accompany request. The National Association of Corrosion Engineers offers no warranty of any nature concerning these sources, and publishes the names for information only.

NACE will NOT accept orders for photoprint or microfilm copies of material not published by the association.

CODE OF AGENCIES SUPPLYING CORROSION ABSTRACTS

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 521 Fifth Ave., New York 17, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EL—Electroplating. 83/85 Udney Park Road, Teddington, Middlesex, England.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

MI—Metallurgia Italiana. Associazone Italiana di Metallurgia. Via S. Paola, 10, Milano, Italia.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

NSA—Nuclear Science Abstracts. United States Atomic Energy Commission, Technical Information Division, Oak Ridge, Tenn.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products. 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

a typical card contains chemical identification and tabular data on such properties as melting point, density, ignition, corrosion and solubility characteristics. The back is devoted to chemical reaction traits, handling and safety suggestions, a brief bibliography and pertinent commercial data such as grades, containers, etc.—BLR.

1.1

Some Aspects of the Problem of Corrosion. Carlos F. Hickethier. *Industria y Quimica*, **12**, No. 2, 43-45 (1950).

A brief and general consideration of the problem of corrosion.—MA.

1.3 Reviews

1.3, 2.3.9

Radioactive Isotopes in Chemical and Industrial Research. H. D. Taylor. *Bull. Brit. Coal Utilisation Research Assoc.* **14**, 293-303 (1950) Aug.

A review. 106 references.—BLR.

1.3, 6.3.10

Nickel and High-Nickel Alloys. H. O. Teeple. Chem. Eng. Materials of Construction. *Ind. & Eng. Chem.*, **42**, No. 10, 1900-2001 (1950) Oct.

Annual review of published references to the use of nickel and high nickel alloys as materials of construction. Alloys containing about 4% or more of nickel or appreciable quantities of cobalt comprise the materials considered. Development of new alloys or improvements in present ones and studies of their physical properties, developments in the fabrication of these alloys, including welding, forming and heat treatments and developments in the applications of these alloys for high temperature and corrosion resistance with reference to the chemical and process industries are included.—INCO.

1.4 Bibliographies

1.4, 4.2.7

Special Bibliography of Reports on Prevention of Deterioration Eguipment and Materials, Including Tropical Deterioration and Fungicides. SB-12. E. A. Tietz. U. S. Office of Technical Services, Wash., D. C. Mar. 1949. 21 pp. Gratis.

1.4, 5.4.5

Bibliography of Reports on Protective Coatings for Metals. SB-2 Revised. U. S. Office of Technical Services, Wash., D. C. July 1950. 21 pp. $0.25 (TA-468, T-25).

1.5 Directories

1.5, 6.1

(1) Chemical Engineering Materials of Construction Review.

(2) Properties of Chemical Engineering Materials of Construction. *Ind. and Eng. Chem.*, **42**, No. 10, 1951-2076 (1950) Oct.

(1) This review based on over 1500 references (mostly 1949-1950), deals with structure; physical, mechanical, and high-temperature properties; corrosion resistance; fabrication; powder metallurgy; applications, etc. The 13 papers include: "Al alloys," by E. D. Verink, Jr. and H. W. Fritts (pp. 1955-56); "Ceramics (and Refractories)," by J. H. Koenig and R. H. Thomas (pp. 1961-70); "Wrought Cu and Cu-Base Alloys" by C. L. Bulow (pp. 1970-77); "Iron, Mild Steels, and Low-Alloy Steels," by C. P. Larrabee and S. C. Snyder (pp. 1986-90); "Nickel and High-Nickel Alloys," by H. O. Teeple (pp. 1990-2001); "Stainless Steels and Other Ferrous Alloys," by W. B. DeLong and P. H. Permar (pp. 2009-19); "Tin and Its Alloys," by R. J. Nekervis (pp. 2019-22); and "Less Common Metals"; by D. B. Broughton (pp. 2023-25), covering titanium, zirconium, tantalum and noble metals. The previous review appeared *ibid*, Oct. 1949.

(2) A series of tables to supplement and revise the information given in the Materials of Construction Data published *ibid*, Oct., 1948. Gives U. S. specifications, physical and mechanical properties, fabrication methods, corrosion resistance, applications, etc., for aluminum alloys, wrought 99.6 percent aluminum, iron and steels, nickel and high-nickel alloys, tin and tin alloys, tantalum, titanium, etc.—BNF.

1.6 Books

1.6, 5.9.1

Modern Developments in Metal Finishing. Edited by Wilfred F. Coxon. 9 x 6 in. 87 p., illustrated. 1950. Beds. Arrow Press Ltd., 29 Grove Road. Leighton Buzzard, England.

The title of this collection of eight lectures, delivered as a special course at the Northampton Polytechnic Institute, London, during the early part of 1950, is more comprehensive than is justified by the contents, which are restricted to specific types of finishing processes. The lecture on phosphate treatments for iron and steel and the three lectures on vitreous enameling are particularly useful in giving a fairly full picture of the background to, and practice of, these processes, while the two lecturets on the finishing of aluminum and magnesium alloys are good summaries of the various modern treatments which are available, without, however, giving data on the protective value of the coatings produced. The two lectures on electro-plating plant and processes contain useful notes on recent developments, presented colloquially for the benefit of the electro-plater. The publication is a handy summary of modern practice in the processes described and its low price should make it attractive to those wishing to obtain general information on these processes.—MA.

1.7 Organized Studies

1.7.2

ASTM Exposure Test Site Program. *Am. Soc. Testing Materials Bulletin*, No. 169, 5-9 (1950) Oct.

A billion dollars is a conservative estimate of the loss each year due to the corrosion of metals. The effects of atmospheric deterioration on plastics, rubber, textiles, wood, and other engineering materials would more than double this figure. The American Society for Testing Materials has long recognized the tremendous economic significance of these problems, and has been one of the foremost contributors to knowledge in these fields by conducting authoritative and impartial atmospheric and other exposure tests that have provided engineers with reliable data for design and operation of structures and equipment of all kinds. This article, after briefly reviewing the Society's accomplishments in a period of some 40 years, presents plans for placing ASTM Exposure Testing on a firm, long-time basis, to assure a continued flow of authentic data on deterioration characteristics of a wide variety of materials, ranging from the various ferrous and nonferrous metals and their alloys through paints, ceramics, rubber, adhesives, plastics, textiles, wood, and "composite" constructions, and invites the financial as well as technical support of the membership and of industry.—TDD.

2. TESTING

2.1 General

2.1.3, 5.4.5

Philosophy of Paint Exposure Testing. C. A. Lominska. *Paint, Oil Chem. Rev.*, **113**, No. 14, 24-32 (1950).

A discussion of paint testing by natural exposure. Accelerated testing in Weatherometers does not give comparable results. This is held to be due to exposure of the film to breakdown forces at a time when it is unduly sensitive. Selection of site and of panel material, positioning of the panels for normal testing, and for testing for resistance to, e.g., chemical staining, mildew, etc., and the exposure of panels for testing ship paints, are described. The effect of misuse of the paint, i.e., the tolerance for over-thinning, etc., is also tested.—RPI.

2.2 On Location Tests

2.2.2, 7.1, 5.9.1, 5.4.5

Third Report of Corrosion Committee IV for the Investigation of Protective Coatings for Iron Structures; Protection With Paint Outdoors. J. Gobel et al. Centraal Inst. Materiaalonderzoek, *Afdel. Corrosie, Mededeling*, No. 26, Part 1, 58 (1949). (In Dutch with English summary.)

A report on exposure tests on steel panels, which were inspected at 6-month intervals; the German DIN scale was used to record breakdown. Pickling and sand-blasting appeared to be equally effective as methods of surface preparation. The addition of 10-20 percent zinc oxide to iron oxide primers considerably improved their performance. The five finishing paints tested were practically of equal merit; these contained white lead, zinc oxide, a mixture of equal parts white lead and zinc oxide, lead titanate and aluminum as pigments.—ZDA.

2.2.2, 5.4.5

Outdoor Exposure of Paints Containing Rutile Titanium Dioxide of Australian Manufacture. J. S. Gourlay. *Paint Notes* (Australia), **5**, No. 6, 175-176 (1950) June.

The results of the outdoor exposure tests so far tend to support those obtained with the weatherometer (see *Paint Notes*, **4**, No. 12, 398 (1949)), best results being obtained with paints containing non-chalking zinc oxide, with or without rutile titanium dioxide.—ZDA.

2.2.2, 2.3.2, 5.4.5

Studies of Weathering of Paints. W. N. B. Armstrong and C. J. Schier-

holtz. *Can. Chem. Process Inds.*, **34**, No. 9, 735-741, 755 (1950) Sept.

Comparative tests between Weather-Ometer and 45 degrees south outdoor exposures on structural finishes and on finishes over galvanized iron are given. Of the structural steel paints, the aluminum-coated panels showed best performance of any of the panels indoors. Outdoors, the difference was not so marked. A black panel with the same primers as one of the aluminum panels, failed sooner indoors but approached that aluminum panel in outdoor performance by giving fair protection at 9-10 years failing completely at 11 years, 7 months. The best black panel outdoors had an oleo-resinous, tribasic lead chromate primer and a black graphite top coat. This primer, however, under indoor black, had no appreciable merit. On the galvanized panels, the Weather-Ometer caused very definite checking of the film which was absent on the outdoor panels. Most of the outdoor panels failed either due to film peeling or marked corrosion pits, or both. The best panels outdoors had primers containing metallic zinc.

Red lead primers showed up poorly outdoors. Absence of peeling on indoor panels with peeling outdoors indicates that the thermal expansion and contraction which occurs outdoors is a major factor in coating galvanizing.—INCO.

2.2.3, 2.3.2, 6.2.5

Comparison of Plant Corrosion Test Results on Austenitic Stainless Steels with Results of Huey and Strauss Tests. H. O. Teeple. International Nickel Company. Paper before ASTM Symposium on Evaluation Tests for Stainless Steels, 52nd Ann. Mtg., Atlantic City, June 30, 1949. ASTM Spec. Tech. Publ. No. 93, 192-199 (1950).

Paper presents certain data on the resistance of some of the austentic stainless steels to corrosion by media encountered in the chemical and process industries in relation to the performance of these same steels in both the Strauss and Huey tests. The plant corrosion data obtained by exposing test specimens in many different plants corrosives are tabulated. Unwelded, as-welded, and welded and heat-treated specimens of Type 304, Type 347 and Type 316 stainless steels were used. Also some tests were made wherein as-welded specimens of 0.03 carbon maximum Type 316 stainless steels were used. The results of boiling nitric acid and boiling acidified copper sulfate solutions provide no basis for comparing the resistance of stainless steels to corrosion by other media. These evaluation tests also fail to indicate the intensity of attack of sensitized material in other media. Tables are included.—INCO.

2.2.3, 4.6.4, 8.9.2

The NBS Simulated Service Corrosion Test for Automotive Antifreeze. *Nat. Bur.* Standards. Letter Circular LC967, Dec. 1949. 7 p., table, diagr.

Information on the corrosive action of antifreeze may be obtained by a method which is intermediate between laboratory tests in glass and engine block tests. Satisfactory solutions are recommended for further evaluation by the engine block method or by actual service. The method has not yet been correlated with service tests.

The test apparatus consists essentially of a closed system in which the circu-

119-1

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lating rate and the temperature of the test fluid can be controlled. It comprises essentially a 3-gallon steel tank as reservoir, a commercial automobile radiator, and a standard belt-driven automotive coolant pump connected by piping and radiator hose. These three parts, as well as the coolant hose, must be new at the start of each test. All component parts are cleaned and degreased before assembly, the assembled unit is flushed at least twice with tap water, and weighed corrosion test specimens are inserted in the reservoir. These consist of six metal discs of different metals of stipulated size and thickness. They are separated by brass spacers, strung on a brass rod, and bolted together. Then the antifreeze to be tested is prepared according to the manufacturer's directions, mixed with tap water (maximum hardness of 113 ppm) in a proportion to give an initial freezing point of 0 degrees F, preferably in the system itself, and the pump is started at 3700 rpm (about 50 mph). The pump speed can be changed by changing the ratio of pulley diameters. Then a hot-plate heating element beneath the tank is turned on an adjusted by a thermoregulator in the coolant circuit to give an operating temperature of 175± 5 degrees F. After all operating conditions have been carefully checked a trial run of 8 hr is made. Thereafter the test unit is operated semicontinuously, viz., on a weekly cycle of 104 hr on with 64 hr off on weekends, for at least 1000 hr, but usually until failure. Periodic inspections of coolant samples and of the corrosion test specimens are made at least weekly. The coolant samples are inspected for rust, dye-fading, darkening, gum formation, and pH change; the corrosion test specimens are weighed. After completion of the test, the unit is dismantled and the parts are inspected for corrosion, wear and other deterioration.—PDA.

2.2.6, 6.3.6, 6.3.8, 6.3.19

Soil-Corrosion Studies, 1946 and 1948: Copper Alloys, Lead, and Zinc. Irving A. Denison and Melvin Romanoff. U. S. Nat. Bur. Standards, Research Paper RP2077. *J. Research Natl. Bur. Standards*, **44**, 259-289 (1950) Mar.

Measurements were made of the corrosion of copper, lead, and zinc and certain of their alloys after exposure to different soil conditions for periods up to 14 yr. Results were compared with the corrosion of wrought ferrous metals under similar soil conditions.

Judged by weight loss, tough-pitch copper was generally more corrosion resistant than deoxidized copper and copper-silicon alloys, except in sulfide-rich soils. Losses in weight of copper-zinc and copper-nickel-zinc alloys increased approximately in the order of increased zinc content, but decreased in this order in soils having high sulfide content. With one exception, all two-phase copper-zinc alloys were dezincified to some extent in most of the soils.

Copper, zinc, lead and their alloys generally corroded more severely in poorly aerated soils, particularly in those soils high in acid or soluble salt content. Copper corroded in sulfide-rich soils. Lead was passivated by soils containing high concentrations of sulfates and chlorides.

For comparing the corrosion resistances of copper, zinc, lead, iron, and steel, the soils were grouped into: 1) well aerated acid soils low in soluble salts, 2) poorly aerated soils, 3) alkaline soils high in soluble salts, and 4) sulfide-rich soils. The ferrous metals corroded at considerably higher rates than any of the other metals, except in Type 4 soil (Rifle peat).

The alloys examined, which were in the form of pipe or plate samples, included tough-pitch copper, deoxidized copper, copper with soldered fittings, red brass, Admiralty metal, leaded silicon brass, yellow brass, Muntz metal, Muntz metal with arsenic, three copper-silicon alloys, copper-nickel-zinc alloy; rolled zinc, die-casting zinc; chemical lead, tellurium lead, antimonial lead, and a special lead alloy. Copper alloys were exposed up to 14 yr, lead and zinc up to 11 yr, and arsenical brass up to 9 yr. The fifteen soils varied from 2.6 to 9.4 in pH, and from 62 to 17,800Ω per cm in resistivity.—TDD.

2.3 Laboratory Methods

2.3.1

Corrosion Testing. T. P. Hoar. *J. Birmingham Met. Soc.*, **30**, No. 2, 63-72 (1950).

Hoar discusses the objects of corrosion testing and reviews the principal methods of assessing corrosion. A number of special techniques are described; these include atmospheric exposure, partial and total immersion tests, the Teddington rotor apparatus, weatherometers, salt spray and humidity cabinets.—MA.

2.3.2, 6.4.2, 3.2.2

Rapid Tests for Intercrystalline Corrosion. Eugene Herzog. *Metal Progress*, **58**, 355-356 (1950) Sept.

Discusses paper by Hugh L. Logan (Feb. issue). Reports similar findings of French laboratory. A similar method was used on aluminum-magnesium and aluminum-magnesium-silicon alloys. Includes Logan's comments.—BLR.

2.3.2, 5.4.5

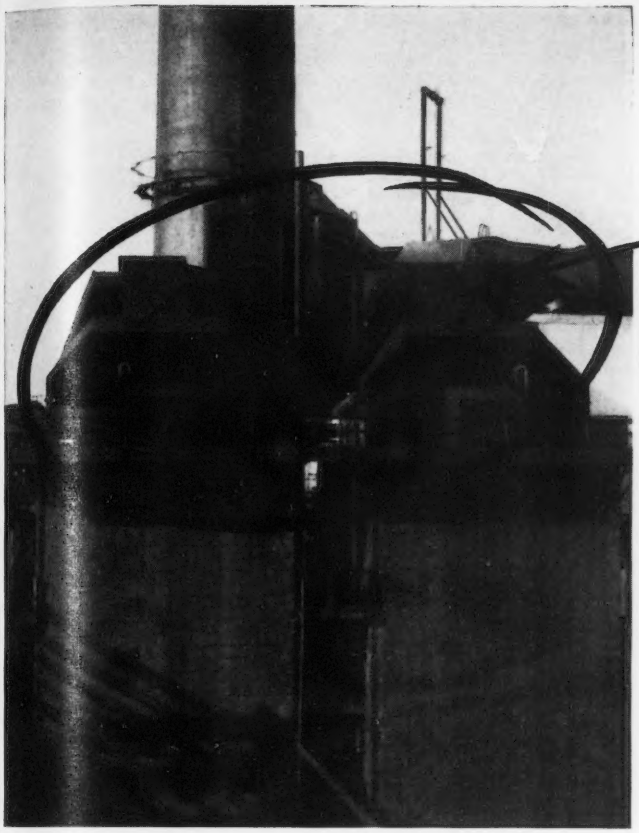
Selection of Protective Coatings for Chemical Fume Resistance. C. C. Harvey. *Corrosion*, **6**, No. 10, 323-326 (1950).

Laboratory and field tests of paints for steel are described with special attention to resistance against hydrochloric acid fumes. The accelerated laboratory test involved storage of panels over 15 percent hydrochloric acid at room temperature. Venyl resin and asphalt mastic coating vehicles showed superior resistance. Red lead was superior to zinc dust or zinc chrome as the inhibitive primer pigment. In field equipment tests, outstanding results were obtained with a medium-oil alkyd-red lead primer with a "flat" chlorinated rubber barrier coat and two vinyl resin finish coats.—RPI.

2.3.2, 6.2.5

Introductory Summary. F. L. LaQue. International Nickel Co. Paper before ASTM Symposium on Evaluation Tests for Stainless Steels, 52nd Ann. Mtg., Atlantic City, June 30, 1950. Am. Soc. Testing Materials, Spec. Tech. Publ. No. 93, 139 (1950).

Purpose of symposium was to permit a critical appraisal of some of the testing methods that were in regular use for evaluating certain corrosion resistant characteristics of these alloys. Special attention was focused on the significance of results of the laboratory evaluation under diverse service conditions, and the effects on behavior of the alloys in test



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and in use of lowering carbon contents to extremely low limits. Summary of entire symposium is given according to composition of testing solutions and duration of exposure to detect sensitization, criteria of satisfactory performance, comparison of results of evaluation tests, reproducibility of results, relation of behavior in common testing solutions to behavior in other media, crucial sensitizing conditions, relation between sigma phase and carbide precipitation, effects of physical nature and distribution of the phase associated with sensitization, information from analysis of residues after corrosion, effect of section size on immunity to sensitization, precision of determination of carbon content, effect of grain size on critical carbon content, effects of composition, and corrosion of weld metal. Tables are included.—INCO.

2.3.2, 5.4.5, 3.6.5

Relation Between the Aging of Paint on a Metallic Base and the Variation of an Electromotive Force. R. Desalme. *Compt. Rend.*, **229,** 873-874 (1949); *J. Iron Steel Inst.* (London), **164,** Pt. 2, 240 (1950).

The emf between a painted metal panel and a platinum electrode in distilled water was measured. After accelerated weathering of the paint the emf rose. It is claimed that measurement of the emf enables the protective quality of the paint to be assessed very quickly. Some results are quoted.—RPI.

2.3.2, 3.2.2, 6.2.5

Some Observations on Tests for Intergranular Susceptibility of 18-8 Mo Stainless Steels. H. Ebling and M. A. Scheil. Am. Soc. Testing Materials, "Symposium on Evaluation Tests for Stainless Steels," Special Technical Publication No. 93, 121-138 (1950).

Points out that a large number of variables exist in present testing practice and that a standard practice should be inaugurated. Using an acidified copper sulfate solution, tests were made on Type 316 heats to determine effects of stabilizing heat-treatment temperature (1550 and 1650 degrees F), time and cooling rate. Other tests were made to study effects of sensitizing at 800 and 900 degrees F for 500 hr after stabilizing heat treatment. Comparison tests were made on Type 316 niobium. Results are tabulated and discussed. Includes micrographs and photographs.—BLR.

2.3.2, 6.2.5

Comparative Corrosion Resistance of Stainless Steels in Various Acids. R. B. Mears, C. P. Larrabee and C. J. Fetner. Carnegie-Illinois Steel Corp. Paper before ASTM, Symposium on Evaluation Tests for Stainless Steels, 52nd, Ann Mtg., Atlantic City, June 30, 1949. ASTM Spec. Tech. Publ., No. 93, 183-187+ (1950).

The corrosion resistances of several grades of austenitic stainless steels were determined in the boiling nitric acid test and compared with the corrosion resistances of these same steels in sulfuric acid solutions. Steels showing the least corrosion resistance in the nitric acid test generally proved to be the most resistant to sulfuric acid. Specimens of Types 304 and 316 stainless steel in both the annealed and sensitized conditions also were exposed to the boiling nitric acid test and to boiling solutions of lactic, phosphoric, and acetic acids. The Type 316 steel proved to be less resistant to the nitric acid, but in most cases was definitely more resistant to the other boiling acids than the Type 304 steel. However, microscopic examination indicated that the types of attack which developed in the annealed or sensitized Types 304 and 316 specimens in the boiling nitric acid test were qualitatively similar to the types of attack which developed in similar specimens in the other boiling acids, provided any attack developed.—INCO.

2.3.2, 5.4.5, 1.7.1

Development of an Accelerated Corrosion Test for Painted Steel in England. H. Van der Veen. *Verfkroniek*, **23,** No. 6, 161-162, 165 (1950).

The work of the Methods of Testing Corrosion Sub-Committee of the Iron and Steel Institute is discussed.—RPI.

2.3.2, 5.5.3

Application of an Accelerated Atmospheric Corrosion Test to the Assessment of Temporary Corrosion Preventives. R. St. J. Preston and E. G. Stroud. *J. Inst. Petroleum*, **36,** 457-463 (1950).

An accelerated atmospheric corrosion test, in which the specimens are exposed at constant temperature to an atmosphere of controlled humidity and containing sulfur dioxide, has been applied in valuing temporary corrosion preventives, including products from lubricating oil, through petroleum jelly, to bitumen. A plain humid atmosphere was not aggressive enough to break down most of the samples, in spite of a prolonged period of test.—PR.

2.3.2, 5.5.3

Use of Weatherometer and Humidity Cabinets for Evaluation of Temporary Corrosion Preventives. W. Pohl. Symposium on the Testing of Temporary Corrosion Preventives. *J. Inst. Petroleum*, **36,** No. 319, 436-448 (1950).

The testing of protectives of the soft-film, solvent-deposited and oil-film types by Weatherometer and humidity cabinet is discussed with special reference to methods of observing and assessing results. Data on a large number of unspecified protectives are presented, but it is concluded that the test methods provide only a qualitative means of comparison. Results from humidity cabinet tests were especially erratic. It is believed that the Weatherometer placed protectives in a reasonable order of merit.—RPI.

2.3.2

Simple Form of Accelerated Corrosion Test. R. St. J. Preston. *Paint Manuf.*, **20,** No. 1, 11 (1950). Discussion, *J. Iron & Steel Inst.*, **165,** Pt. 3, 287-289 (1950).

Specimens are subjected to corrosion in a warm humid atmosphere containing sulfur dioxide. The importance of controlling the sulfur dioxide concentration is stressed. Corrosion rates increase with rise in temperature and increase in sulfur dioxide concentration.

2.3.2, 6.2.5

Accelerated Corrosion Testing of Chromium-Nickel Stainless Steel Weldments. F. K. Bloom and M. E. Carruthers. Am. Soc. Testing Materials, "Symposium on Evaluation Tests for Stainless Steels," Special Technical Publication No. 93, 1950, p. 87-100+ (TA479.S7 Am35s).

Describes 3 common tests and compares their results with field experience using a welded pickling tank. The nitric-hydrofluoric acid test appeared to be the most severe criterion of susceptibility to weld decay. Includes tables and micrographs.—BLR.

2.3.2, 6.2.5

An Appraisal of Methods for Evaluating the Corrosion Resistance of Stainless Steels. M. H. Brown, W. B. DeLong, and W. R. Myers. Am. Soc. Testing Materials, Symposium on Evaluation Tests for Stainless Steels, Special Technical Publication No. 93, 1950, p. 103-119+.

Compares 3 test methods and considers the effect of alloy composition on routine nitric acid tests on stainless castings. Discusses value of tests compared to service failure. Includes graphs and illustrations.—BLR.

2.3.4

Photoelectric Determination of Atmospheric Sulphur Dioxide. M. Katz. *Anal. Chem.*, **22,** No. 8, 1040-1047 (1950). —RPI.

2.3.5

Use of a Magnetic Field in Detecting Corrosion Currents. F. Blaha. *Nature*, **166,** 607 (1950) Oct. 7.

When a drop of potassium chloride solution is placed on an abraded iron surface, corrosion occurs at the center of the drop as a result of currents flowing between the well-aerated, cathodic periphery and the less-aerated, anodic, center. Such a drop placed on a pole piece of an electromagnet will rotate when the magnetic field is turned on, the direction of rotation depending on the polarity of the field. A method of roughly estimating the strength of the current by measuring the velocity of rotation of the drop is described.

2.3.5, 5.2.1, 8.9.3

Surface Potential Method of Corrosion Survey of Pipelines. O. W. Wade. *Corrosion*, **6,** No. 10, 341-343 (1950) Oct. —BNF.

2.3.5, 3.6.6, 5.2.4

Studies on Galvanic Couples. I.—Measurement of Electromotive Force and Internal Resistance of Cells During Current Flow. II.—Some Potential-Current Relationships in Galvanic Corrosion. III.—Polarization and Cathodic Protection. H. D. Holler. J. Electrochem. Soc., **97,** No. 9, 271-280; No. 12, 453-461 (1950). *Corrosion*, **7,** No. 2, 52-68 (1951) Feb. Discussion, *J. Electrochem. Soc.*, **98,** No. 6, 252 (1951) June.

I. Method of measuring simultaneously the effective electromotive force and internal resistance of a galvanic cell during current flow is described. The technique is dealt with in detail and a dry cell was used for demonstrating the method, which employs a bridge and potentiometer. By introducing a reference electrode into a cell consisting of an iron electrode and a magnetite electrode in wet clay, it was possible to measure the two quantities described between the reference electrode and one of the other two. When the iron and the magnetic were short-circuited, the potential and resistance between the reference electrode and the iron-magnetite couple were measured. By impressing current on the galvanic couple from an

auxiliary electrode the potential-current characteristics of the couple was determined. The use of both a potentiometer and a bridge enabled differentiation to be made between the emf component and the resistance component of a potential difference to some extent. It was shown that the iron plate in wet clay exhibits a potential-current characteristic similar to that of the galvanic couple.

II. A graphical method of expressing the electrical characteristics of a galvanic couple was developed by the application of Kirchoff's laws to a couple consisting of separate electrodes, each with an ammeter in series. It was possible to establish a definite current pattern by impressing an external emf between the couple and a third electrode, also with an ammeter in series. This pattern depended on the relative directions and magnitudes of the impressed emf and the potential of the couple. Under the conditions used, a discontinuity in the potential-current relation was observed when the couple was cathodically polarized over a sufficient range of current, a discontinuity which coincided with the reduction to zero of the current circulating within the couple. It is concluded that the measurement of the potential of the iron/hydrogen couple by any suitable method and its relation to the polarizing current may serve to indicate

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the magnitude of the protective current. Such an indication would be sharp in air-deficient conditions, and as these conditions are frequently encountered in cases of underground corrosion, then if the relations established in this work can be applied to pipe-lines and other underground structures, it may be possible to evaluate the total galvanic current flowing in the phase boundary and therefore the rate of corrosion at the moment. Moreover, it may be possible to estimate how much externally applied potential or current is required to stop corrosion.

III. The mechanism of the polarization of a galvanic couple is developed and the roles of electrode potentials and of resistive-potential differences are demonstrated in polarization and cathodic protection by means of separate elements in an electric network. Several methods of showing the relation between polarizing current and galvanic-couple potential are discussed, and the electrical conditions which determine the distribution of current flowing to a galvanic couple are defined. It is shown that under laboratory conditions of restricted aeration in wet clay, polarization of an iron-hydrogen couple by an applied current may be used to evaluate the internal current and therefore also the applied potential and current required for the cathodic protection of iron. The application of these principles to cathodic protection when the ratio of cathodic to anodic area is very large and the full importance of the principle of current partition to current distribution should be studied for long distances underground. The criterion of cathodic protection based on applied potential may be useful, particularly where the open-circuit anode potential may vary with conditions and with time. Application of the required const. potential, the applied current adapting itself to that necessary to maintain the const. potential, should result in economy of power. An explanation of hydrogen overvoltage on the basis of polarization of galvanic couples in the phase boundary is suggested.—MA.

2.3.5, 3.5.8, 6.4.2

The Fundamentals of Corrosion of Metals Under Stress — Part I — Aluminum. P. F. Thompson. Aeronautical Research Laboratories Report S. M. 143 (Australia) January 1950.

Potential-time curves on stressed and unstressed commercial purity aluminum were determined in distilled and tap water and salt solution. No appreciable difference in potential was found between stressed and unstressed material except when the stress was sufficient to rupture the oxide film.—ALL.

2.3.6

Three New Etchants for Non-Ferrous Metals (Copper, Copper Alloys, and Nickel). Charles T. Flachbarth and Chester S. Pondo. *Metal Progress,* **56,** No. 5, 688-691 (1949).

These reagents are intended for: a) copper, brasses, and phosphor bronzes, b) nickel specimens where grain-boundary clarity is required, and c) nickel specimens where contrast is required. They have been named Pondo's reagent and Precision No. 1 and Precision No. 2. The first is made up from chromic acid, hydrochloric acid, ammonium hydroxide and hydrogen peroxide; the second from nitric acid, acetic acid, cupric ammonium chloride and ammonium hydroxide; the third from hydrofluoric acid, acetic acid, nitric acid, ammonium chloride, ammonium hydroxide and sodium dichromate. 12 photomicrographs are reproduced.—MA.

2.3.6

Surfaces of Solids. XXI. Areas of Non-Porous Solids from Adsorption Isotherms of n-Heptane or n-Hexane. Edward H. Loeser and William D. Harkins. *J. Am. Chem. Soc.,* **72,** 3427-3431 (1950) Aug.

Presents results of an investigation of use of the adsorption isotherms of n-heptane or n-hexane for determination of the areas of solids by the BET and the Harkins-Jura relative methods of calculation. Results indicate that values calculated by the HJ method are consistent with those calculated by the BET method, provided certain limitations are observed.—BLR.

2.3.6, 3.5.8

Caustic Etching Detects Fatigue Damage (of Aluminum Alloys). Paul W. Boone. *Iron Age,* **165,** No. 20, 99-100 (1950) Aug.

Boone describes the application of caustic soda etching in the detection of fatigue cracks in aluminum alloys. Small parts are etched in a 5-20 percent solution for 3-15 min. and examined at 10 or 20 magnifications; larger parts require a 40 percent solution for 30-60 min. Care must be taken to avoid splashing the caustic solution.—MA.

2.3.7

Abrasion Resistance and Its Measurement. J. M. Buist. *Trans. Inst. Rubber Industry,* **26,** 192-217+ (1950) Oct.

The relation between abrasion resistance and the simpler physical properties and use of the regression technique whereby equations relating abrasion resistance, tension strength and hardness have been developed are discussed. 21 existing abrasion machines are reviewed and classified. Work with 8 sole and heel compounds and 12 tire treads shows that order of merit obtained in the normal Du Pont test is almost completely the reverse of service. With the tire-tread compounds, extraction of the test pieces in ethanoltoluene azetrope improved correlation with service.—BLR.

2.3.7, 3.5.8, 5.3.2

Fatigue Tests on Hard-Chromium-Plated (Steel) Specimens. Walter Eilender, Heinrich Arend, and Eugen Schmidtmann. *Metalloberflache,* **3,** No. 8, 161-163 (1949).

A study was made of the effects of hard-chromium plating on the fatigue strength of steel rods. The results show that the decrease in fatigue strength, which becomes greater with thickness of the coating from 0.02-0.5mm, is not due to hydrogen absorbed during the plating process, but is brought about by the incipient cracks which are present in the coating. These develop during the alternating-stress testing and cause a roughening of the steel at the interface, thereby producing notch effects which lead to local increases in the stress concentration. Annealing at 250 degrees C for two hr causes the cracks to become larger and leads to further decreases in the fatigue strength. It is concluded that when fatigue stresses are to be encountered the thickness of chromium coatings should not exceed 0.03 mm.—MA.

2.3.7, 3.5.9, 6.2.5

Thermal Shock Test of High Temperature Alloys. H. S. Avery and C. R. Wilks. Alloy Casting Bulletin. May 1950, pp. 1-9. Abstracted in *The Nickel Bulletin,* **23,** 162 (1950) Aug.-Sept.

Materials used for equipment operating at high temperatures are chosen primarily on the basis of the structural strength at service temperatures and their resistance to corrosion by air or other atmospheres. The authors emphasize the importance of resistance to cyclic temperature changes, as a further factor

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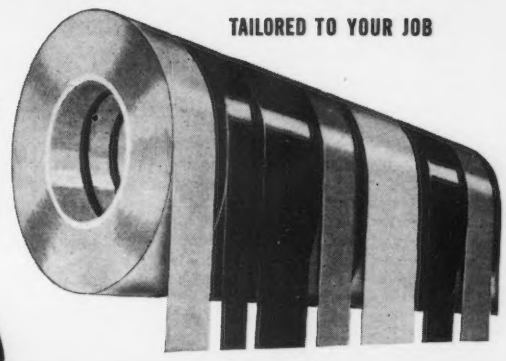

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which must influence selection of materials for many applications. Evaluation of resistance to deterioration as a result of the stresses imposed in cyclic heating and cooling has hitherto been possible only by consideration of the record of individual cases of service behavior, but the authors have developed a test which is believed to be capable of discriminating among the various high-temperature alloys with regard to their relative resistance to thermal fatigue. The test provides for sudden and large variations in temperature and the design of the test piece is such as to incorporate stress-raisers equivalent to those which, in service, frequently accentuate the influence of sudden temperature fluctuations. The cycle of heating and cooling simulates service involving alternate heating and water quenching, with the important difference that industrial service usually involves longer times of heating. Using the apparatus described, thermal-fatigue tests were made on partially ferritic and substantially austenitic grades of 26-12 chromium-nickel-iron alloys, and 35-15, 60-12, 68-18 and 20-26 percent nickel-chromium-iron alloys, in various conditions. The results are reported in detail.—TIME.

2.3.9, 3.4.6, 4.6.7

Study of the Process of Oxidation (Rusting) of Iron with the Aid of Oxygen Isotopes. E. I. Dontsova. *Doklady Akad. Nauk, S.S.S.R.,* **63,** 305-306 (1948).

In the course of geochemical studies on the isotope content of oxygen in minerals, as a method of determining the genesis of rocks and minerals, the author made several experiments on the oxidation of iron in river water. The rusting took place in the presence of air containing various quantities of the isotope 0.[18] As a result, it was found that water, not air, is the main source of oxygen in rust and that the part played by the atmospheric oxygen in the process of rusting is that of a depolariser.—RPI.

2.3.9, 1.4

Bibliography of Publications Dealing with the Polargraphic Method in 1948. J. Heyrovský and O. H. Müller. *Coll. Trav. Chim. Tchecoslov.,* **14,** No. 8, 569-594 (1949).—MA.

2.3.9

Radioactive Isotopes of Iron and Their Application in Chemistry and Biology. (In Russian.) V. I. Goldanskii and M. B. Neiman. *Uspekhi Khimii* (Progress in Chemistry), **19,** 320-341 (1950) May-June.

Discusses, on the basis of the literature, physical characteristics of iron isotopes, iron[52] to iron,[59] production of test specimens of radioactive iron and application in chemistry, metallurgy, biochemistry and biology.—BLR.

2.3.9, 6.4.2

The Oxidation of Evaporated (Layers of) Al-Mg and Al-Ag Alloys in a Vacuum. (In German.) A. Boettcher. *Z. angew. Physik,* **2,** No. 6, 249-251 (1950) June.—BNF.

2.3.9, 7.1

Micrographic Inspection of A Heat-Resisting Alloy for Turbine Blades. P. A. Jacquet. *Rev. de Metallurgie,* **47,** 568-572 (1950) Aug.; Mond. Gen. Refer. Sheet, Ser. No. 686, 4 (1950) Sept. 9.

Description of special micrographic technique developed to examine incidence of break-down of cohesion in samples of French material similar to Nimonic, after routine cold-fracture tests of blade tips Method is believed to have wider application in study of structure of high-alloy content nickel-chromium alloys during creep at high temperatures. Some experiments showing structural alterations in creep specimens determined by the new method are described. Specimens are first subjected to electrolytic polishing in acetic-perchloric acid bath and are subsequently treated in a very dilute solution of sodium hyposulphide at c.d. of 1-2 amp. /dm² for 10-30 seconds. This is followed by cathodic cleaning in 2 percent solution of sodium hydroxide for 4 minutes at 7 amp. /dm.² Notes on causes and nature of the phenomena observed are given.—INCO.

2.3.9

More Users for Radioactive Tracers. *Iron Age,* **166,** 73 (1950) Sept. 28.

Outlines method described by J. Kronsbein at the recent AES Convention in Boston for measuring thickness of very thin deposits and for accurate tracing of current distribution.—BLR.

2.4 Instrumentation

2.4.2, 4.6.4

Comparator for Corrosion Control of Coolants. *Diesel Progress,* **16,** No. 8, 93 (1950) Aug.

A new slide comparator was developed for corrosion control in the cooling fluids of air conditioning systems, refrigerating brines, diesel engine cooling systems, condenser cooling water, etc. With a single slide comparator, it is possible to check the pH and the chromate content. Manufactured by W. A. Taylor & Co.—INCO.

2.4.2, 2.3.2

Testing Multiple Specimens of Stainless Steels in a Modified Boiling Nitric Acid Test Apparatus. W. B. DeLong. DuPont. Paper before ASTM Symposium on Evaluation Test for Stainless Steels, 52nd Ann. Mtg., Atlantic City, June 30, 1949. Am. Soc. Testing Materials, Spec. Tech. Publ. No. 93, 1950, 211-214.

Description of an apparatus in which a number of specimens can be exposed simultaneously, the use of which will result in appreciable savings in cost, acid, power and laboratory space. This can be done provided the chromium ion content is not excessive. Graph showing effect of chromium content in 65 percent nitric acid on the corrosion of stainless steel is given.—INCO.

2.4.3

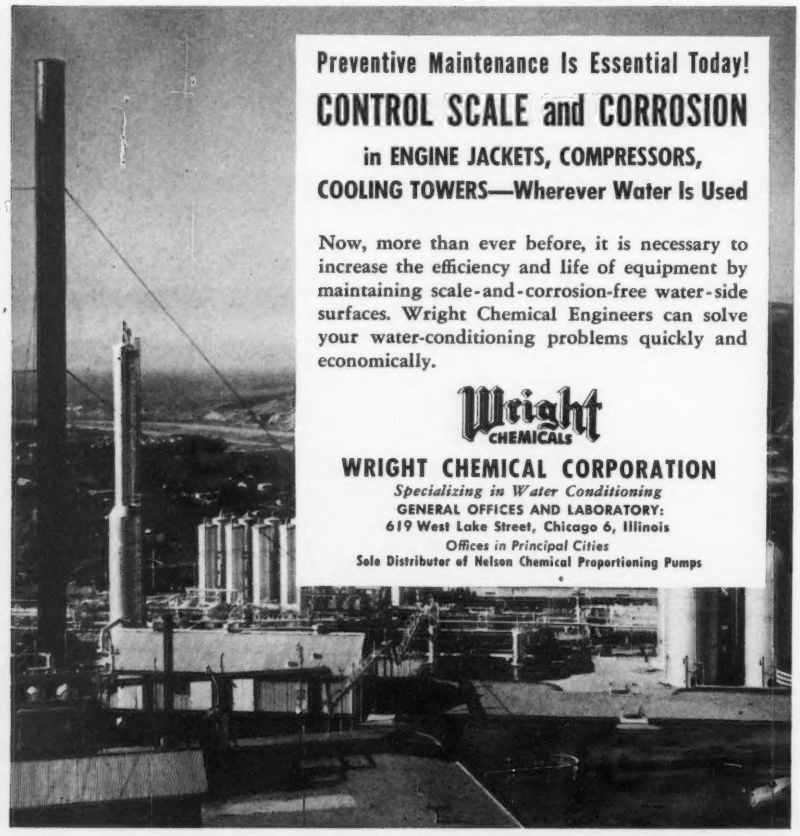
Non-Destructive Testing of Castings. (In English.) L. Van Ouwerkerk. Metalen. Internat. Gieterij Congres 1949, 1950, 288-298+.

Ouwerkerk reviews the following non-destructive methods of testing castings: radiography, ultrasonic examination, magnetic and electrical testing. The applications of each method in the inspection of light alloy, copper-base and ferrous castings are considered.—MA.

2.4.3

Measurement of Metal Thickness from One Side. Dwight J. Evans. *Petroleum Refiner,* **28,** No. 12, 109-112 (1949).

An instrument is described which op-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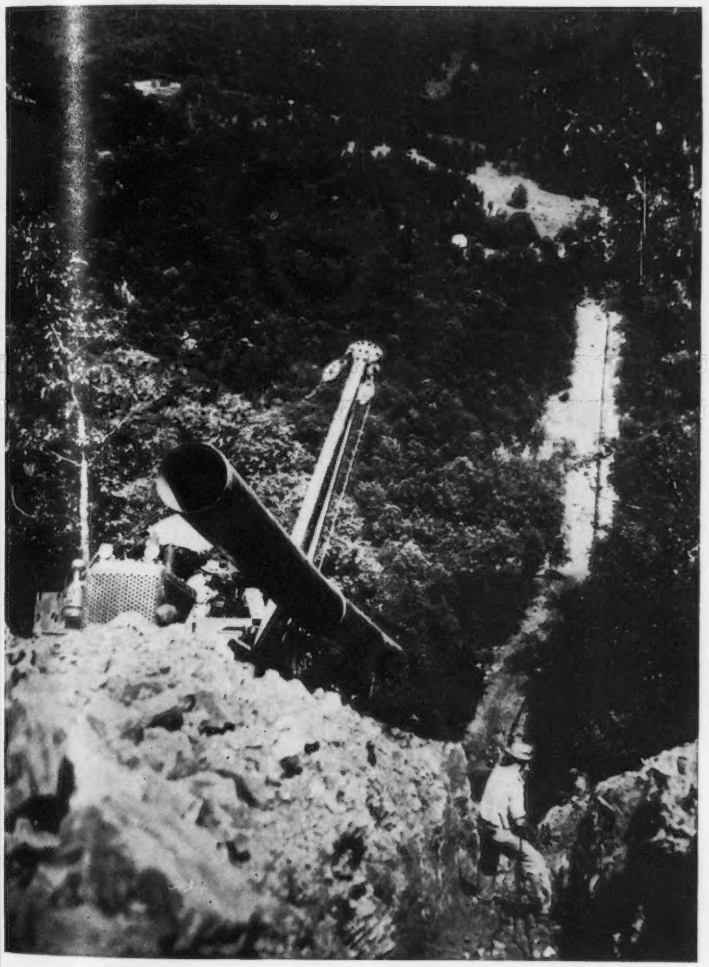

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erates on the ultrasonic-wave principle and which measures thickness by determining the frequency at which resonance of the ultrasonic waves occurs. It has a range of 1/16-12-in. of steel, and may be used to measure the thickness of other materials such as brass and aluminum. A number of applications, entirely to ferrous metal equipment used in oil refineries are briefly described.—MA.

2.4.3
Special Methods of Examining Metals. C. O. Lloyd. *Practical Eng.*, **21,** No. 536, 482-483 (1950).

A general account is given of the use of X-rays, electron diffraction and ultrasonics in the examination of metals.—MA.

2.4.3
Ultrasonics Determine Life of Diesel Engine Crankshaft. *Iron Age,* **166,** No. 5, 78 (1950) Aug. 3.—MI.

2.4.3
Radium Used in Water Pipe Examination. *Iron Age,* **165,** No. 17, 98 (1950) Apr. 27.—MI.

2.4.3
Oil Powder Method of Flaw Detection. *Industry and Welding,* **23,** No. 5, 27, 76-77 (1950) May.

An oil powder method has been developed by the Navy for detecting surface cracks and discontinuities in metals and other dense materials. The importance of flaw detection is that by discovery of incipient defects, only microscopic in size, failure under service conditions can be prevented. This method has many advantages over other flaw-detection procedures, but the outstanding virtue is its simplicity. Penetrating oil is applied to the surface to be inspected, removed a minute later, and then the detecting powder is dusted on. The tracery of the surface flaws appears as a sharply defined red line on dull white background of the detecting powder. The oil powder method of inspection is applicable to both ferrous and nonferrous metals, enamel, plastics, or any other dense material. This method can be used for flaw detection in all types of machinery components, weldments and plane or ship hulls. With no auxiliary equipment, it permits simultaneous coverage of an entire surface. Hundreds of square feet of metal surface, such as the entire surface of a large plane, can be inspected in approximately one hour's time.—TDD.

2.4.3
Current Applications of Magnetic Analysis Inspection. V. L. Spoley. *Non-Destructive Testing,* **8,** No. 4, 20-23 (1950).

A description is given of the use of magnetic methods for: 1) detecting defects, such as sub-surface cracks and laps in bars and tubing, 2) thickness gauging, 3) detecting variations in analysis, or in hardness, in pipes and bars.—MA.

2.4.3
Sonic Tests Spot Flaws in Heavy Forgings. Robert W. Snowden. *Iron Age,* **165,** No. 15, 77-81; No. 17, 88-90 (1950).

Snowden gives illustrations of the sonic testing of heavy forgings, including oscilloscope photographs of all types of common defects. Sonic testing of irregular shapes requires special techniques and equipment; certain areas on eccentric cranks must be critically scanned; and drill collars are tested with two different types of searching unit.—MA.

2.4.3, 3.7.4
Are You Overlooking Ferromagnetic Analysis? J. K. Stanley. *Steel,* **127,** 88-92 (1950) Oct. 2.

Shows that magnetic measurements are extremely valuable in interpreting metallurgical phenomena in nondestructive testing, stress analysis and in structural studies. Typical data are charted and discussed.—BLR.

2.4.3, 1.3
Magnetic Particle Inspection. L. A. Danse. *Non-Destructive Testing,* **8,** No. 4, 7-12 (1950).

An historical review is given of the progress in America of magnetic methods of crack detection, from 1917 to date. Reference is made to the use of both colored and fluorescent magnetic inks and powders, to a magnetic method for rating the cleanliness of steel, and to modern equipment which magnetizes the component in two directions simultaneously, thus revealing defects lying in all directions at one operation.—MA.

2.4.3
Ultrasonic Testing of Tool Steels. J. C. Hartley and E. K. Mull. *Iron Age,* **163,** No. 20, 80-85 (1949) May 19.—MI.

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.2, 6.3.6, 3.7.2, 3.4.6
Intercrystalline Corrosion of Copper-Silicon Alloys Caused by Atmospheric Oxygen. (In German.) Otto Heusler. *Z. Metallkunde,* **41,** 261-264 (1950) Aug.

Oxidation of copper-silicon alloys containing 15-40 percent silicon was studied. At higher temperatures, the accumulated heat of reaction may cause spontaneous combustion. Small additions of arsenic, bismuth, germanium, lead, tin, thallium or atmospheric moisture accelerate, beryllium and zinc decelerate rate of oxidation. The reaction was studied at different temperatures and with addition of 26 different elements. Includes photographs, micrographs, charts and tables.—BLR.

3.2.3
The Effect of Deformation of the Surface Layers of Metal During Oxidation. (In Russian.) P. D. Dankov and P. V. Chursev. *Doklady Akad.* Nauk SSSR (Reports of the Academy of Sciences of the USSR), new ser., **73,** 1221-1224 (1950) Aug. 21.

The phenomenon of torsion of isolated protective oxide layers observed for the first time by Evans and assumed by him to be a direct result of stresses formed during oxidation of the surface layer of metal was investigated. Results obtained for iron and magnesium clearly indicate the presence of the above deformation and make it possible to evaluate its magnitude approximately. Data are tabulated and charted.—BLR.

3.2.3, 6.3.21
The Law of Oxidation of Metallic Cerium: Generalization for Other Metals. Jean Loriers. *Compt. Rend.,* **231,** No. 10, 522-524 (1950).

Loriers calculated the mechanism of dry oxidation as a function of the time on the assumptions that the process of oxidation of cubic cerium is the result of the superposition of the two elementary reactions: $2Ce + 3O \rightarrow Ce_2O_3$ (cubic), and $Ce_2O_3 + O \rightarrow CeO_2$ (*ibid.,* **229,** 547 (1949), and Courtel and Loriers., *ibid.,* **230,** 735 (1950); that the sesquioxide is formed by diffusion according to a parabolic law under a continuous skin (Trombe and Foex, *Ann. Chim.,* (xi) **18,** 97 (1943), while the less volatile dioxide is formed by the direct contact of Ce_2O_3 with oxygen according to a linear law. Experiments at low temp. on face-centered cubic γ-cerium showed that at 20° C the protective influence of the sesquioxide predominates. Between 40° and 130° C the slope of the final rectilinear part of the curve increases with the temp. At ~130° C the initial curved part becomes negligible. Even at temp. close to the ignition point of the metal (290°-320° C) there still remains a very thin film of cubic Ce_2O_3 joined to a zone of solid solutions, which permits a very rapid diffusion of oxygen and constitutes a kind of oxidation front that progresses faster as the temp. is raised. The law enunciated has been established only for cerium and has not been confirmed for other metals; but it appears that it can be generally laid down that the action of a gas on a metal gives rise to a protective film that changes to a porous layer at a const. rate. The oxidation of uranium could be so interpreted.—MA.

3.2.3, 6.2.2
Crystallochemical Mechanism of the Formation of an Oxide Film on Iron at Room Temperature. (In Russian.) P. D. Dankov and N. A. Shishakov. *Zh. Fizicheskoi Khimii,* **23,** No. 9, 1031-1035 (1949) Sept.—BNF.

3.2.3, 2.3.9, 6.4.3, 4.3.5, 3.5.9
The Kinetics of the Reactions of Beryllium with Oxygen and Nitrogen and the Effect of Oxide and Nitride Films on Its Vapour Pressure. Earl A. Gulbransen and Kenneth F. Andrew. *J. Electrochem. Soc.,* **97,** No. 11, 383-395 (1950).

A study is described of the reaction of beryllium with oxygen over the temp. range 350°-950° C in high vacua, using the vacuum microbalance method. The experimental data comply with the parabolic rate law except for the initial period. No colored films were observed for a 2-hour oxidation at 600° C, but above this temp. colored oxides formed. A comparison of oxidation rates showed that beryllium reacts at 825° C at about the same rate as zirconium at 375° C. The initial reaction rates showed beryllium to react at about the same rate as the Nichrome V series of alloys at 900° C. The energy of activation calculated from the temp. dependence of the parabolic-rate-law constants is 50,300 calories per mole. Vacuum-treated beryllium has the smallest parabolic-reaction-rate constant at 900° C of any metal or alloy studied. The reaction of beryllium with nitrogen was investigated over the range 600°-925° C. Colored films were observed after 2-hour reactions at 725° C and higher. The reaction was not sensitive to changes in pressure, and the data could be fitted to the parabolic rate law. The rate of reaction with nitrogen was somewhat smaller than with oxygen. The energy of activation is 75,000 calories per mole, calculated over the temp. range 725°-925° C, a value which is

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close to $\Delta H\Theta^\circ$ for the evaporation of beryllium. The entropies and free energy of activation were calculated, and positive entropy was found. No appreciable reaction between beryllium and hydrogen was discovered over the temp. range 300°-780° C for a pressure of 2.3 cm mercury. The vapor pressure of beryllium was also studied and an investigation of the influence on it of oxide and nitride films was made. Oxide films exert a strong effect in reducing the vapor pressure, the effect varying as the square root of the oxide thickness. A film of 99 γ/cm^2 lowers the vapor pressure 100-fold. A nitride film of 42 γ/cm^2 reduces the vapor pressure 4-fold.—MA.

3.2.2, 3.4.3, 6.3.10

Green Rot of Electrical Resistors. T. Bishop. *Metal Progress,* **58,** No. 3, 356 (1950) Sept.

Approximately 2 silicon in a nickel-chromium-iron resistor alloy is sufficient to prevent carburization on atmospheres containing both carburizing gases and combined oxygen. The inhibiting effect of silicon may be associated with the nature of the oxide film on the film. This effect may be confined to the interface between metal and oxide in the form of a barrier film rich in silica, and may be due to some ability of silica to seal rifts in the oxide layer.—INCO.

3.3.2, 4.6.11, 6.5

Effect of Barnacles and Corrosion on Metals and Alloys Suspended in Sea Water. S. Thayer. *Corrosion* (News Section), **6,** No. 9, 1 (1950) Sept.

Tabulation of observations made of several metals and alloys which were submerged in sea water for 110 days. A steel rod encased in copper was covered with barnacles but there was no evidence of corrosion. A 10-10 steel plate was covered with barnacles and badly pitted. A Mayasir steel plate showed the same results as the 10-10 steel plate. On a galvanized steel plate there were no barnacles nor any sign of corrosion. Illustrations.—INCO.

3.2.3, 2.3.9, 6.2.2

An X-Ray Study of the Scale Formed on Iron Between 400° and 700° C. A. O. Tesche. *Trans. Am. Soc. Metals,* **42,** 641-652 (1950).—MI.

3.2.3, 6.2.5

Formation of Oxides on Some Stainless Steels at High Temperatures. H. M. McCullough, M. G. Fontana, and F. H. Beck. *Am. Soc. Metals.* Preprint No. 4, 1950, 17 pages. (TS300 Am35t.)

Describes the continuous weighing apparatus used and the study of the course of oxide growth on Types 304, 430 and 410 steels from 1500° to 1800° F. Dried oxygen, nitrogen, and their mixtures constituted controlled furnace atmospheres. Results are tabulated, plotted and discussed.—BLR.

3.3 Biological Effects

3.3.4, 7.2

Clues to Bacterial Corrosion. F. E. Kulman. Cons. Edison Co. of N. Y., Inc. *Am. Gas Assoc. Monthly,* **32,** No. 10, 26, 30 (1950) Oct.

Explanation of the electro-biochemical approach to underground metal corrosion and coating deterioration. Bacteria cause changes in the physical and chemical properties of the soil which result in corrosion by differential aeration and chemical attack. The most severe corrosion of underground pipe occurs in dense, poorly aerated soils containing organic matter. Saprophytic bacteria deplete the oxygen content of the soil, removing the oxide film on the metal pipe and causing the metal to become anodic with respect to pipe areas relatively more aerated. Sulfur oxidizing bacteria become active when soil conditions become aerobic. They oxidize sulfide to sulfate and produce sulfuric acid which causes chemical attack.—INCO.

3.4 Chemical Effects

3.4.8, 4.3.6, 3.6.8, 6.3.6

The Rate of Corrosion of Copper in Salt Solutions. W. Katz. (In German.) *Metalloberflache, Ausgabe A,* **4,** No. 7, A101-A104 (1950) July.

Study of the kinetics and mechanism of the corrosion of copper in solutions of magnesium chloride, the effect of aeration and impurities (cupric sulfate) in the solution, the size of the cathode surface, etc. The corrosion is often regarded as a cathodically-regulated process.—BNF.

3.4.9, 4.3.6, 6.2.3

The Corrosion of Steel by Sea Salt of Given Moisture Content. S. J. Duly. *J. Soc. Chem. Ind.,* **69,** 304-306 (1950) Oct.

The moisture content of the residue obtained by evaporating sea water is shown to be determined by the relative humidity of the air in which it is subsequently kept, provided that the storage temperature does not vary. Samples of such sea salt corrode mild steel in proportion to their moisture contents. The extent of corrosion of mild steel by sea salt is therefore governed by the relative humidity of the ambient air and keeping the moisture content of the salt-complex at 8 percent or less substantially prevents corrosion from this cause.

3.5 Physical and Mechanical Effects

3.5.3, 5.10

Carbon Restoration Improves Wear Resistance. Samuel Damon. *Steel,* **127,** 66-67 (1950) Oct. 23.

Tells how surface physical properties, including wear resistance and fatigue strength of steel parts decarburized by hot forming, can be greatly enhanced by recarburizing during heat treatment in a controlled atmosphere.—BLR.

3.5.5, 5.4.5

Porosity of Paint Films. B. L. Harris and I. Wolock. Official Digest Federation Paint & Varnish Production Clubs, **1950,** No. 308, 645-648, Sept.

A report on experiments designed to find out whether films of linseed oil varnish allow the permeation of water vapor through pores. The method used was to measure the apparent surface area of film specimens by the degree of absorption of krypton at liquid nitrogen temperatures. The average surface was only 17 percent greater than the geometrical area, so it is concluded that film porosity is insignificant in its contribution to permeability. Extraction of the specimens with acetone made little difference to the area indicating a simple roughening of the surface without penetration of the film.—ZDA.

3.5.3, 1.7.1

Cavitation Problems. Wheeler. Paper presented at the July 1950 Conference of the British Hydromechanics Research Association. British Hydrodynamics Research Association. Report on July 1950 Conference.

Outlines the research into cavitation problems which the author is carrying out at Mark Laboratories on behalf of the association. We first showed that there can be two distinct cases of cavitation attack on metals: one, where the stressing due to the bubble collapse is above the fatigue limit of the metal erosion will occur due to fatigue, whether corrosion of the metal by the liquid occurs or not, the effect of corrosion being to increase the rate of attack; the second, where the stressing is below the fatigue limit of the metal, and attack will only occur if there is corrosion of the metal by the liquid. The author describes the apparatus he is constructing in order to investigate these points. A small sample of the metal under investigation is plugged into the end of a nickel tube which can be oscillated at a frequency of 10,000 cycles per second by a magneto-striction oscillator driven by an alternator. The sample is immersed in a small quantity of liquid contained in a breaker. Precautions are taken to cool the nickel tube and to control the temperature of the liquid. The virtue of this method is that the nature of the liquid used can be carefully controlled and all the metal removed from the specimen by corrosion and mechanical erosion can be recovered. It is proposed to detect the small amount of metal in solution by colorimetric methods. In the discussion of the paper attention was drawn to the case of the boiler feed pump handling pure de-aerated water, and it was stated that in this case the cavitation effects did not differ from those obtained with ordinary water. Reference was also made to the practice of admitting a little air to the water entering a pump or turbine in orer to reduce the effects of cavitation.—TIME.

3.5.8, 6.4.2, 3.2.2

Appearance and Interpretation of Stress Corrosion in Malleable Aluminum Alloys. (Concluded.) H. Vosskuhler. *Werkstoffe u Korrosion,* **1,** 310-320 (1950) Aug.; 357-366 (1950).

Discusses effects of annealing above the solubility temperature; of alloying additions; of harmful impurities; and of structural anisotropy. Sept. issue attempts to explain stress corrosion caused by electrochemical and mechanical action and by a combination of the two. Distinguishing characteristics of stress corrosion, intercrystalline corrosion, and laminar corrosion are briefly discussed. Includes tables, graphs, diagrams, X-ray patterns, photomicrographs, and 13 references.—BLR.

3.5.8, 1.3, 8.9.1

Fatigue of Structures and Structural Members. (In Dutch.) H. P. Van Meer and F. J. Plantema. Nationaal Luchtvaarlaboratorium (Amsterdam), Report S. 357, Aug. 18, 1949, 39 pp B.N.F. Serial 34,284.

A survey of the literature following on one issued in 1945. Covers general prin-

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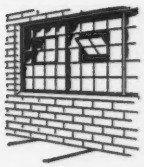

ciples including definitions, factors relating to fatigue strength, statistical theory, methods of improving fatigue strength, and fatigue strength of structural components (mainly joints) common in aeronautical design; light alloys and steels. Authors consider that present knowledge is not satisfactory even with regard to simple test specimens. Some suggestions are made for investigations to be carried out at the N.L.L. (National Luchtvaartlaboratorium). Over 100 references.—BNF.

3.5.8

The Fracture of Metals. Institution of Metallurgists, London. 138 pages. 1950.

Lectures delivered at the Institution's Refresher Course 1949: "Introduction," Maurice Cook; "Cohesion and Rupture in Metals," N. P. Allen; "Fracture in Creep," R. W. Bailey; "Fracture Under Fatigue Conditions," H. L. Cox; "Fracture Due to Stress Corrosion," U. R. Evans; and "Effects of Rate of Loading on Fracture of Metals," C. Gurney.—BLR.

3.5.8, 3.2.2

The Influence of Stress on Corrosion. Part II. J. J. Harwood. *Corrosion,* **6,** No. 9, 290-307 (1950) Sept.

Localized corrosion attack develops pits or trenches as a result of the presence of anodic zones which develop from composition or strain gradients or from local breakdown of protective corrosion films. Regions of stress concentration which are favorable to the initiation of cracks are thus formed. These cracks are propagated under the combined action of stress and corrosion. Satisfactory methods for preventing and eliminating stress corrosion in many specific systems have been developed. The principal factors involved are stress, environment, composition, internal structure and time. Accelerated laboratory tests are described which are not representative of service conditions, but they furnish valuable information concerning the stress-corrosion behavior of alloys and the mechanisms of stress-corrosion cracking. Theories which have been formulated on stress-corrosion include the electrochemical theory, film theories mechanical theory, strain accelerated decomposition theory, and orientation effects. The nature of stress corrosion cracks in magnesium alloys are predominantly transgranular; there is no recorded case of failure due to applied service stress—residual stresses resulting from fabrication or assembly operations produce failure; magnesium alloy sheet which has received a precipitation treatment before cold rolling is less apt to crack than cold rolled or recrystallized sheet. Satisfactory methods of preventing stress corrosion have been developed by the use of barrier coatings, stress relieving heat treatments, proper design and fabrication procedures, cathodic protection and the introduction of surface compressive stresses. A bibliography of 81 references is included.—ALL.

3.5.8, 3.7.4

On the Problem of the Formation of Fatigue Microcracks. G. V. Karpenko. *Doklady Akademii Nauk SSSR,* **74,** No. 1, 95-98 (1950).

Dynamics of process of fatigue failure in polycrystalline aggregates. Role of adsorption-active media in deformation, with special reference to ultramicrocracks and to fatigue limit. Relationship between surface finish and grain size, on the one hand and fatigue limit, on the other. Conclusions drawn from author's results as to proper machining practice for minimizing fatigue microcracks. Translation available from Henry Brutcher, Box 157, Altadena, Calif.

3.5.9, 6.2.5

An Analysis of Temperature Distribution in a Metal Hollow Cylinder of Finite Radius Under Unsteady State Conditions from E.E.S. Data. R. J. Knox (USN). *J. Am. Soc. Naval Engr.,* **62,** No. 3, 587-599 (1950) Aug.

As part of a series of tests to determine the effects of thermal shock on steam piping for naval use, this investigation is concerned with just what the temperature distribution is in the pipe wall before steady state conditions are attained. Tests were run on a length of 25-20 chromium-nickel, ¾ in IPS, schedule double extra strong pipe using saturated steam, superheated steam and exhaust gas as the heating media. One of the thermocouples used was #29 B & S gage Fe-constantan. In addition to these runs a series of tests was made on similar samples of 18-8 chromium-nickel steel pipe. Analytic and graphitic solutions for temperature distribution are discussed. Graphs are given.—INCO.

3.6 Electrochemical Effects

3.6.1

Some Applications of Electrochemical Thermodynamics. M. Pourbaix. *Corrosion,* **6,** No. 12, 395-404 (1950) Dec.

The affinity and velocity of an electrochemical reaction, the magnitude and sign of which can be measured, are discussed with consideration of all the electrochemical phenomena which can take place on the same metallic surface. The study is facilitated by the knowledge of the polarization curves. This treatment is applied to the behavior of iron in the presence of aqueous solutions (behavior of electrically insulated and non-insulated iron; influence of oxidizing agents upon the potential and upon the speed of corrosion, etc.). These principles also have been applied to fundamental study of the reactions between hydrogen and some oxidizing substances on a platinum surface, which was published by Wagner and Traud in 1938.—TDD.

3.6.5, 6.4.2, 3.4.3

Studies on the Formations of Barrier Anodes of Aluminum. K. Guminski and Z. Seweryn. *Bull. Intern. Acad. Polon. Sci.,* **A,** No. 5-6, 91-99 (1949) May-June.

Experiments are discussed on aluminum anodes formed in a solution of oxalic acid to a determined potential difference with a constant current; a) curves for dependence of current intensity on voltage; b) with an applied lower constant potential difference, the reading of the current intensity during a period of time. The data indicate the formation of thick layers to be connected with their constant dissolution and re-formation, and so with a larger participation of ion conduction. In dilute solution, where the dissolution is small, the electron conduction plays the major role. The thick layers have a more amorphous and less coherent structure, while the thin layers are more crystalline.—ALL.

3.6.5, 4.6.6, 3.4.8

Electrochemical Behavior of Zinc and Steel in Aqueous Media. Part II. R. B. Hoxeng. *Corrosion,* **6,** No. 9, 308-312 (1950) Sept.

Shows that constituents present in natural waters have a pronounced effect on the electrochemical behavior of zinc. In laboratory tests it was found that the effect of cadmium, even in small amounts, was to shift the potential of zinc in the anodic direction. Silicate additions likewise promote anodic zinc potentials, tending thereby to decrease the possibility of reversals in zinc-steel couples. Additional laboratory data confirm earlier evidence that temperature is secondary to electrolyte composition in its effect on the above.—BLR.

3.6.6, 3.8.2, 4.4.6, 4.4.2

On the Electrochemical Character of the Corrosion of Metals in Liquid Dielectrics. L. G. Gindin. *Doklady Akad. Nauk SSSR,* **73,** No. 3, 515-518 (1950).

Experimental refutation of theory that there exists a fundamental difference in the mechanism of corrosion processes in electrolytes and nonelectrolytes. Observation of character of corrosion (potential distribution and corrosion pattern) in a short-circuited iron-magnesium cell in a 1.5 N solution of acetic acid in isooctane. Particulars on apparatus used for study of functioning of above cell. Results of study and conclusions as to electrochemical character of corrosion processes in dielectrics and the functioning of macro as well as microcells. Translation available Henry Brutcher, Box 157, Altadena, Calif.

3.6.6

Formation and Effect of Galvanic Currents. (In German.) L. W. Haase.

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Werkstoffe u. Korrosion, **1,** 297-299 (1950) Aug.

Presents evidence which shows that corrosion of metals is often incorrectly blamed on galvanic action. Claims that corrosion is sometimes caused by solution and deposition of one metal on another metal, the other metal then being destroyed by action of the resulting local currents.—BLR.

3.6.8

Investigations of the Cathodic and Anodic Behaviour of Metals. VII. R. Pointelli and G. Poli. *Gazz. chim. ital.* **79,** 863-867 (1949); *Chem. Abs.* (U.S.A.), **44,** No. 15, 6746 (1950) Aug. 10. (Seen in abstract form only.)

The authors investigated the barrier polarization phenomena of solutions of a number of zinc salts at 25° C and at 50° C. The results make it possible to interpret some anomalies in the behavior of zinc, e.g. the small influence of the current density and of the temperature and the greater barrier effects than would be expected from its atomic characteristics and lattice.—ZDA.

3.6.9, 5.2.1

Electrolytic Corrosion and the General Theory of Corrosion. Gasworks Safety Rules Comm., Rept., Inst. of Gas Engineers 16th Autumn Research Meeting, London, Nov. 28-29, 1950.

Potential measurements between different underground structures are not in themselevs indicative of the degree of corrosion danger to affected structures, but they do provide indication to danger areas that can be subjected to more vigorous and quantitative tests. Current measurements should also be treated qualitatively. All apparatus should be installed with dust-excluding casing, preferably cast iron and maintained dust-free. Leakage and anode protection were also discussed.

3.7 Metallurgical Effects

3.7.2, 4.3.2, 6.3.8, 7.10

The Anodic Corrosion of Large-Surfaced Lead Plates With Small Alloying Additions in Lead-Sulfuric Acid Storage Batteries. (In German.) W. Hofmann and H. G. Petri. *Werkstoffe u Korrosion,* **1,** 232-238 (1950) June-July.

Effects of 0.002-0.05 percent silver, arsenic, cobalt, copper, mercury, nickel, antimony, tin and zinc on the above were studied. The batteries were charged and discharged up to 1000 times each. Anodic corrosion was studied on the basis of changes in capacitance of the lead, dimensions and weight of the plates, of sludge formation and by microscopic observation. Includes tables, graphs and micro- and macrographs. Continuation of earlier work in 1943 and 1946.—BLR.

3.7.2, 6.2.5, 1.3

Alloying Elements in Chromium-Nickel Stainless Steels. Helmut Thielsch. *Welding J.,* **29,** 361s-404s (1950) Aug.

Information and data which have become available on stainless steels during the past decade are reviewed and correlated. Particular emphasis is placed on effects of the various residual and alloying elements on physical and welding metallurgy of the major grades of stainless steel. For comparison, available information on wrought and cast grades is also presented. Effects of the various elements on structure and on corrosion resistance, and of thermal treatments are also described. Welding-electrode and electrode-coating compositions are discussed.—BLR.

3.7.2, 3.2.2, 6.2.5, 2.3.2

Influence of Carbon and Molybdenum on the Intergranular Corrosion Resistance of Austenitic Chromium-Nickel Steels With and Without Columbium. W. O. Binder and C. M. Brown. Am. Soc. Testing Materials, "Symposium on Evaluation Tests for Stainless Steels," Special Technical Publication No. 93, 1950, p. 146-171+ (TA479.S7 Am35s).

Compares intergranular corrosion tests made on 5 types of 18-8 steel containing 0.06 and 0.03 percent maximum carbon, including molybdenum and molybdenum-niobium (columbium) variations. The nitric acid test reveals intergranular attack due to phase formation and to chromium carbide precipitation, however, another test must be used to distinguish between the two causes.—BLR.

3.7.3, 7.1, 6.2.5

Heat Treatment of Steel Forgings for Gas Turbines. H. W. Kirkby. Brown-Firth Research Lab. *Metallurgia,* **41,** No. 246, 317-320 (1950) Apr.

The development of the long-life gas turbine for use in power stations and for marine propulsion has resulted in a demand for large forgings of materials capable of operating at high temperatures for long periods. In order to develop the required properties, it is necessary to carry out heat-treatment operations at temperatures of the order of 1200° C, followed in some cases by quenching. This combination of large mass and high temperature is unique in the heat-treatment field and many metallurgical and handling problems arise. The heat-treatment of gas-turbine steels offers no serious difficulties in the case of the normal ferritic steels and the lower-grade austenitic steels. Problems arise, however, when dealing with large forgings in the more complex austenitic steels because of the high solution temperatures employed. To date, the approach to the heat-treatment of alloys in this latter category has, on the whole, been conventional, wide use being made of existing plants but with additional precautions.—TDD.

3.7.3

The Effect of Cold-Work on Steel. Sec. VII-General Discussion. *J. Iron & Steel Inst.,* **165,** Pt. 4, 389-395 (1950) Aug.

The results reported in sections I-VI of this paper are correlated and discussed. It is concluded that the austenite theory is valid only in special cases involving the sudden generation of intense heat during deformation. In normal processes of cold-working, the austenite theory is untenable and the change of properties is explained by the various effects of internal strains in ferrite and in cementite. While the effect of internal strains in ferrite is to some extent well known, the effect of such strains in cementite and of those arising from the mutual restraint between ferrite and cementite, upon the bulk properties of steel, has not been sufficiently realized. The increased hydrogen saturation in cold-worked steels has also been correlated with X-ray line-broadening, thus supporting the view that the hydrogen introduced into steel at room temperature is mainly accommodated in occluded form at crystallite boundaries or mosiac disjunctions.—INCO.

3.7.3, 6.2.5

Welding Stainless Steel Pipe. Allen J. Ely, Jr., I. *Heat & Vent.,* **47,** No. 2, 63-67 (1950) Feb.; II. *Ibid,* No. 3, 70-72 (1950) Mar.

Grooves or crevices on the interior surface of stainless steel piping serve as focal points for concentration cell corrosion. Therefore butt-welded joints should be used wherever possible, with butt-welded flanged joints at points where the system must be broken. The ASA has established the Schedule 10 S series of stainless steel pipe which weighs up to 50 percent less than standard pipe (Schedule 40 S) yet is heavy enough to retain adequate stiffness and rigidity. When chrome-nickel stainless steels are heated to 800°-1,600° F, chromium carbide is precipitated to the grain boundaries which permits intergranular corrosion due to depleted chromium at the boundaries. This harmful precipitation may be prevented by use of stabilized stainless steel containing niobium which has a greater affinity for carbon than does the corrosion resistant chromium, or by restricting the percentage of carbon in the stainless steel to 0.03 percent. The grades having very low carbon are becoming increasingly prominent as substitutes for niobium stabilized grades due to the restricted supply of niobium. Inert-arc welding should be used wherever possible. Either alternating or direct current can be used; straight polarity direct current is recommended. Physical and chemical properties of commonly used stainless steels are presented.—RA.

3.7.4

The Crystallite Theory. II. *Metal Ind.,* **77,** No. 11/12, 147 (1950) Sept. 22.

Investigations were continued on the theory that when a metal is deformed plastically it breaks down into small, relatively perfect fragments called crystallites. The main point at issue is still concerned with the question of whether the line broadening observed in back-reflection X-ray patterns from cold-worked metals is caused by small fragments of crystal or whether it is due to severely distorted lattices. Attention is also being given to the possibility that, under certain conditions of straining, a metal crystal may be broken down into much larger subunits or cells. A method of examining the specimens is described, as well as the results obtained at room and high temperatures.—TDD.

3.7.4, 7.6.3, 6.2.5

The Influence of Precipitations at the Grain Boundaries on the Resistance of Chromium-Nickel Steels to General Corrosion. L. Piatti. *Sulzer Tech. Rev.,* No. 1, 27-31 (1950); *Engrs. Digest,* 11, No. 9, 11 (1950) Sept.

A laboratory autoclave of austenitic 18/8 steel showed that corrosive attack had been concentrated on the hemispherical bottom and on one of the plates forming the inner wall. No difference in the corrosion resistance of the two metals could be found in their chemical composition. X-rays revealed a lower lattice constant for the austenite crys-

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tals of the hemispherical bottom than for those of the unaffected segments. The chromium content was lower (1 percent absolute) in the corroded metal and very slight differences in the composition of the single crystals may affect the resistance to corrosion. For metal equipment coming in contact with highly aggressive substances, investigation into the composition of single crystals must be included in any material testing program. Illustrations.—INCO.

3.8 Miscellaneous

3.8.3, 3.4.6, 6.2.5, 6.4.2

Letters to the Editor—The Corrosion of Aluminum. J. M. Bryan and T. N. Morris. Dow Temp. Research Station. *Chemistry & Industry*, No. 34, 638 (1950) Aug. 26.

Tests carried out on a number of chromium-nickel steels showed that, while all the samples withstood attack by a dilute solution of citric acid at 25° C in the presence of air, one of them suffered considerable attack in the absence of air, but only after abrasion with emery. Both chromium-nickel steels and aluminum owe their protection to a surface film of oxide and there seems no doubt that in these cases the surface film, disrupted through abrasion, is readily repaired through oxidation of the metal by dissolved oxygen. (See Report of the Food Investigation Board for the Year 1933, 152.)—INCO.

3.8.4, 3.6.1

Reductive Dissolution of Ferric Oxide in Acid. I—Reductive Dissolution of Oxide Films Present on Iron. II—Reductive Dissolution of Powdered Ferric Oxide. III—The Mechanism of Reductive Dissolution. M. J. Pryor and U. R. Evans. *J. Chem. Soc.*, 1259-1276 (1950).

The rate of autoreduction in dilute acid of thin films of ∝ ferric oxide on iron increases with a decrease of film-thickness, with a decrease in pH and with an increase in the temp. of the electrolyte. Potential measurements show that reductive dissolution is highly polarized and that polarization increases with a rise in pH. With powdered samples of the ferric oxide, reductive dissolution, at pH values below 2.0, is controlled by surface conductivity. The effect of dissolved oxygen as a cathodic depolarizer becomes more pronounced as the current density decreases. It is believed that the reductive dissolution of ferric oxide involves the combination of hydrogen atoms, discharged at the oxide surface, with oxygen ions to form either hydroxyl ions or water mols. which pass into the solution.—RPI.

3.8.4, 2.3.9

Study of Mechanism of Corrosion. N. Hackerman. *World Oil*, **130**, No. 5, 188 (1950) Apr.

The mechanism of metal corrosion is being studied with the aid of stearic acid containing radioactive carbon (C^{14}) at The University of Texas' Corrosion Research Laboratory. Disposition of the acid molecules on the surface of the steel is being traced to locate points of active corrosion. Since exposed metal presents a non-uniform surface, it corrodes in different ways at different points. A flow system of pipes has been installed in the laboratory to study corrosion under simulated gas-condensate well conditions.

4. CORROSIVE ENVIRONMENTS

4.2 Atmospheric

4.2.1, 3.4.8, 3.8.3

Adsorbed and Reaction-Product Films on Metals. Herbert H. Uhlig. *J. Electrochem. Soc.*, **97**, 215C-220C (1950) Nov.

Discusses effects of gaseous atmospheres on metals, encountered at room and elevated temperatures, during processing, storage and use. Among the topics considered are wetting of iron by mercury, physical adsorption, chemisorption, chromium and the stainless steels, chloride ions and pitting action of hydrogen, passivation, adsorption vs. reaction and adsorption of metals on metals.—BLR.

4.2.3, 7.10, 4.6.6

Condensation in Gas Water Heaters. Committee on Domestic Gas Research, Project DGR-6-WH. Am. Gas Assoc. Research Bull. No. 58, 47 pp. (1950) Oct.

Original data presented and analyzed indicate that for all practical purposes the type of metal usually employed and the emissivity of its surface have no effect on the rate of condensation of water vapor from flue gases. On the other hand, the presence of sulfur in a fuel gas raises the dew point temperature of the flue gases and increases the formation rate of condensate on metal surfaces. Metal surfaces studied are reflecting and black body surfaces of copper, galvanized iron and Monel. Data are also presented and discussed on the effect of type and emissivity of a metal surface and condition of such surfaces on water side on the rate of transferring heat to still water and on the rate of condensate elimination. These data indicate that rate of transferring heat to water and rate of condensate elimination are greater for dropwise condensation than for filmwise condensation. Heat transfer and rate of condensate elimination are also increased by changing a metal surface from reflecting condition to a black body condition. Increasing thermal resistance such as scale formation on water side of a metal results in a decrease in heat transfer and no significant change in the rate of condensate disappearance.—INCO.

4.3 Chemicals, Inorganic

4.3.2, 6.2.5, 6.3.10, 6.3.13

Corrosion. M. G. Fontana. *Ind. and Eng. Chem.*, **42**, No. 9, 111A-112A (1950) Sept.

Metals and alloys generally used and suitable for handling hydrochloric acid are discussed. Nominal compositions of seven alloys for hydrochloric acid service are listed and the characteristics of the alloys are outlined. Durichlor, a high silicon cast iron containing molybdenum, shows marked passivity in that initial rates of corrosion are fairly high, but corrosion decreases rapidly with time. It is used in industry over the entire concentration of hydrochloric and muriatic acids at temperatures below 200° F. Aside from Durichlor and tantalum, all of the materials listed are nickel-base alloys; Chlorimet 2 and 3, and Hastelloy A, B and C.—TDD.

4.3.2, 6.5, 1.3

Alloys Resistant to Hydrochloric Acid. B. Waeser. Lecture before Achema 9, 1950. *Werkstoffe u Korrosion*, **1**, 345-349 (1950) Sept. 1.

Review of recent developments, in sections dealing with behavior of non-ferrous metals and alloys, cast irons, high nickel-chromium steels and nickel-base alloys of the Hastelloys and kindred types. Work in progress use of inhibitors are discussed.—INCO.

4.3.2, 6.1

Hydrochloric Acid Versus Construction Materials—II, III, IV. Edmond C. Fetter. *Chem. Eng.*, **56**, No. 1, 231 (1949); No. 2, 243; No. 3, 251.

II.—Carbon and graphite, tantalum Chlorimet, and Worthite are discussed with regard to their resistance to corrosion by hydrochloric acid. III.—Precious metals, silicones, glass pipe, Durimet 20, and nickel and its alloys are considered. IV.—Chemical stoneware, glass-lined steel, and protective coatings are briefly dealt with. Part I published in Dec. 1948 issue *Chem. Eng.*—MA.

4.3.2, 4.3.5, 6.5

Corrosion of Metals in Fluorine and Hydrofluoric Acid. G. C. Whitaker. *Corrosion*, **6**, No. 9, 283-285 (1950) June.

Experience gained over a period of years in the use of metal equipment for the production and handling of fluorine and for the production and shipment of hydrofluoric acid has resulted in an accumulation of information relative to the behavior of metals under various conditions. None of the common metals or alloys have been found to be universally applicable and even the nobler metals such as platinum and silver have developed shortcomings under certain conditions. Of the common commercial metals the nickel-copper alloys such as Monel have been found most versatile. However, severe corrosion has been encountered under some conditions. Nickel proved to be excellent for service with fluorine to relatively high temperatures. Mild steel has been used extensively in fluorine cell construction and has proved adequate for the storage and shipment of anhydrous hydrofluoric acid. Steel drums and tank cars have been used for a number of years for the shipment of the higher strengths of aqueous hydrofluoric acid. Copper tubing, because of its convenience and copper pipe have been used in hydrofluoric acid service but due to sensitivity to high velocity corrosion should be used with caution. The stainless steels have proved of little service because of a pitting type of corrosion. Lead which was used almost exclusively in aqueous hydrofluoric acid service, has been replaced by other metals and by synthetic rubber.—EL.

4.3.2, 4.3.6, 6.2.2

The Effect of Acid and Neutral Phosphate Solutions on Ingot Iron. II. (In German.) H. Grubitsch. *Werkstoffe u Korrosion*, **1**, 303-304 (1950) Aug.

Results of a study of corrosion of iron containing 0.045 percent carbon, 0.056 percent silicon, 0.40 percent manganese, 0.031 percent sulfur and 0.015 percent phosphorous in acid and neutral solutions of sodium monabasic ortho-phosphate are charted and discussed.—BLR.

4.3.2, 5.8.3, 2.3.4, 6.5

The Rate of Corrosion of Metals in Acid Solutions Containing Depolarizers. Melvin Hochberg and Cecil V. King.

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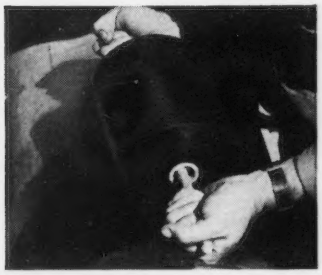

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J. Electrochem. Soc., **97**, No. 6, 191-197 (1950).

The results are presented of a survey of the action of depolarizers in aqueous acids, mainly dyes whose redox potentials were known or could be measured. It was not possible to establish a definite relationship between dissolution rate and potential of the oxidant-reductant, metal-metal ion system. Full details of the experimental method used are presented. Over 50 oxidizing agents were tested, and of these 27 were sufficiently soluble in dilute acid and showed some depolarizing action. The metals examined were cadmium, tin, lead, and copper, and reactions are described whose rates are: 1) diffusion controlled, 2) chemically controlled, 3) partly diffusion, partly chemically controlled, 4) subject to inhibition by reduction products or intermediate products.—MA.

4.3.3, 6.4.2

Choice of a Light Alloy for Articles in Contact with Alkali Lyes. Jean Dupont and Pierre Tyvaert. *Fonderie*, **53**, 2062 (1950).

The effect of the use of industrial alkaline solutions on aluminum is described. For the best resistance to this form of attack the alloys A-S4G (41SM) and A-G3T are recommended.—MA.

4.3.6, 6.1

Corrosion Experiments with Gaseous Baron Trifluoride. F. Hudswell, J. S. Nairn and K. L. Wilkinson. AERE-CR-468, 10pp (1950) June.

Several construction materials were contacted with gaseous boron trifluoride at an original fixed pressure at 25 cm of mercury, and at temperatures up to 200° C. Reaction extent was indicated by change in gas pressure over the sample. Many materials showed a high resistance to chemical attack by boron trifluoride.

4.4 Chemicals, Organic

4.4.6, 8.9.3

Vanadium in Crude Oils — Effect on Steels or Alloys. *Oil Gas J.*, **49**, No. 35, 65 (1951) Jan. 4.

4.5 Soil

4.5.1, 6.4.2, 3.7.3, 3.6.6

Underground Corrosion Tests on Aluminium Alloys at Wright-Hargreaves Mine. H. P. Godard and K. Winslow. *Can. Mining Met. Bull.*, **43**, No. 462, 552-557 (1950) Oct.

A number of panels of various aluminum alloys in different combinations and secured by steel and three types of aluminum rivets were exposed underground at two locations in a Northern Ontario gold mine for two years and then examined to determine the extent of corrosion. The results indicate Alcan 65S-T to possess considerable advantages over Alcan 17S-T, which has been employed in the construction of light skips and cages with considerable success for almost twenty years. Information on the behavior of these alloys when used with steel rivets and in mixed combinations with themselves was obtained. The deterioration of aluminum in the vicinity of steel rivets was the most common corrosion problem encountered. There are two causes for corrosion in this location: galvanic corrosion between the dissimilar metals and metallurgical alteration of 17S-T alloy to a structure that has a considerably lowered corrosion resistance, caused during the insertion of the hot steel rivets.—ALL.

4.6 Water and Steam

4.6.12, 8.4.3

Problems Encountered in Conditioning Water for Subsurface Injection. G. G. Bernard. Pure Oil Co. Paper before ACS, Symp. on Conditioning Water for Repressuring Oil Fields and for Underground Disposal, Houston. *Oil Gas J.*, **49**, No. 23, 101-102+ (1950) Oct. 12.

Experiences in conditioning a number of typical oil-field waters for subsurface injection. Sequestration of iron, corrosive and supersaturated water, hydrogen sulfide brine, effect of vacuum on stability of calcium carbonate, chlorination problem, mitigating corrosion and incompatible brines are included in the discussion.—INCO.

4.6.12, 8.4.3

Conditioning Water for Secondary Oil Recovery in Appalachian Fields. J. N. Breston. Penn. Grade Crude Oil Assoc. Paper before A.C.S., Symposium on "Conditioning Water for Repressuring Oil Fields and for Underground Disposal," Houston. *Oil Gas J.*, **49**, No. 16, 159-160+ (1950) Aug. 24.

Discussion on treating water for flooding purposes includes requirements for ideal water, water treatment (aeration and chemical), settling, filtering, algae and bacteria growths, deaeration and deactivation, treatment of brines and amine treatment for bacteria and corrosion control. Most of the water treatment methods attempt to produce a calcium carbonate or complex P scale to prevent corrosion. However, producers in the Appalachian area are using a slightly corrosive water with strict exclusion of dissolved oxygen. The water is treated with amine type chemicals. These are potent bactericides and cationically surface active. They are readily absorbed onto metal surfaces and greatly reduce corrosion rate. Rosin Amine D Acetate, Pur-O-San, Arquad S and 2C are some of these.—INCO.

4.6.2, 5.7.7

Solution to Your Problems in Feedwater Treatment. R. C. Ulmer. E. F. Drew & Co., Inc. *Ind. and Power*, **59**, No. 1, 81 (1950) July.

In this, the second of a two-article series, measures for preventing turbine deposits and condensate line corrosion are considered.

The use of an amine or an ammonium organic is suggested for raising condensate pH to overcome corrosion.

The first of this series, in the June, 1950, issue, discussed treatment practices for preventing difficulties in feedwater and boiler systems.

4.6.4, 3.3.2

Maintenance of Heat Transfer by Cooling Water Treatment. W. A. Hall and Roy F. Weston. *Ind. and Eng. Chem.* **41**, 1409-1412 (1949) July.

A method is described for evaluating exchanger fouling in terms of throughput capacity. Data are presented to show control of bacterial fouling by either chlorination or the addition of phenolic-type compounds.—RA.

4.6.11, 6.3.2, 6.3.3, 6.3.4

Corrosion of Iron and Steel in Sea Water. F. C. Hudson. *J. Iron Steel Inst.*, **166**, 123-136 (1950) Oct.; *Chem. Age*, **63**, 836 (1950) Dec. 16.

The results so far obtained in the course of the Corrosion Committee's work relating to the corrosion of structural irons and steels when immersed in sea water are presented and examined. The presence of mill scale on the iron or steel is shown to promote serious pitting in sea water. The rate of general corrosion of mild steel when immersed in British waters after removal of the mill scale is found to be approximately 3-5 mils per year. There is little, if any, difference in the corrosion rates, under these conditions, of ordinary unalloyed ferrous materials, such as mild steel, ingot iron or wrought iron. Of a wide range of alloying elements incorporated in a series of low-alloy steels, only two, chromium and nickel, are shown to have any significant effect in reducing the corrosion rate. Steels containing 2-3 percent of chromium were found to corrode at one-half or one-third of the rate of unalloyed steels of the same carbon content. The effect of nickel additions were less marked. No significant difference has been observed in the behavior of ordinary and of copper-bearing steels when totally immersed in sea water.—TIME.

4.6.12, 5.8.2

Chemical Treatment of Flood Waters Used in Secondary Oil Recovery. V. P. Gregory, C. R. Groninger, and J. H. Prusick. Armour Develop. Lab. Paper before ACS, Symposium on Conditioning Water for repressuring Oil Fields and for Underground Disposal, Houston. *Oil Gas J.*, **49**, No. 17, 74-76 (1950) Aug. 31.

A series of tests were run to determine which long chain fatty amine or amine salt was the most effective inhibitor of corrosion of metal equipment and plugging of injection wells. Dicoco amine dimethyl ammonium chloride (Arquad 2C) is an effective corrosion inhibitor; more so than the amine acetates tested. Tests with HCl and sulfuric acid show that a smaller concentration (than 10 ppm) is as effective in corrosion inhibition as a larger concentration of amine acetate. A combination of three chemicals is necessary for complete chemical treatment of flood waters used in secondary oil fields. An economical inorganic anti-oxidant, a quaternary ammonium compound and a wetting agent are the three specific chemicals.—INCO.

4.7 Molten Metals

4.7

Influence of Previous Oxidation on the Corrosion of Cast Iron by Molten Aluminum and Light Alloys Containing Silicon. (In French.) P. Bastien and P. Azou. *Fonderie*, No. 55, 2111-2121 (1950) July.

A continuation of work previously reported by Bastien and Daeschner, see B.N.F. Bulletin 231, Sept., 1948, p. 286. Experiments in which the cast iron specimens were oxidized for periods up to 48 hours at 850° C, before being tested in molten aluminum, aluminum-12 silicon showed that slight oxidation (up to 8 hr.) increased the resistance of all types

of cast iron, grey cast iron being once the most resistant, but intense oxidation (48 hr.) was deleterious to malleable cast iron and to mild steel, though it improved the resistance of cast iron containing 32 percent chromium.—BNF.

5. PREVENTIVE MEASURES

5.2 Cathodic Protection

5.2.1, 1.2.2, 8.9.3

Cost and Savings Effected by Cathodic Protection for a Short Section of Line. J. F. Stephenson. Gulf Refining Co. *Oil Gas J.*, **49**, No. 20, 240-241 (1950) Sept. 21.

The application of cathodic protection on 10 pipe lines in the same right-of-way near Gulf's Port Arthur refinery has afforded savings in money, materials and shutdown time. This article gives informative details on the subject.—INCO.

5.2.1, 1.2.2, 8.9.3

Annual Cost of Corrosion to U. S. Gas and Oil Lines Is Estimated at $600,000,000. S. E. Trouard. Am. Gas Assoc. Meet., Atlantic City, Sept. 19, 1950. *Oil Gas J.*, **49**, No. 22, 128 (1950) Oct. 5.

Cathodic protection and the use of thinner walled pipe were recommended.

5.2.1

Rectifiers and Galvanic Anodes for Cathodic Protection. A. L. Stegner. *Proc. Amer. Gas Assoc.*, **1949**, 669-673.

The advantages and disadvantages of the two methods are considered and a number of practical applications of each type of system are described.—MA.

5.2.2, 8.9.3

Pipeline Corrosion and Its Control by Cathodic Protection. T. R. B. Watson. *Can. Oil Gas Ind.*, **1950**, 41-42 July.

The author discusses the cause and prevention of galvanic corrosion in pipelines. Magnesium anodes for cathodic protection are usually installed about 10 feet from the pipe. The anodes must raise the potential of all parts of the pipe to 0.85 volts negative to a copper/copper sulfate electrode, in contact with the earth, to give satisfactory protection.—INCO.

5.2.2, 6.4.2

Cathodic Protection With Aluminum. Technische Rundschau (Germany) No. 37 (1950) Sept. 15. *Light Metals Bulletin* (England) **12**, No. 22, 865-866 (1950) Oct. 27.

It has been calculated that for anodes for the protection of underground pipelines and the like, magnesium is 1.6 and zinc 1.8 times as expensive as aluminum. When using aluminum (usually aluminum-zinc alloy containing 1.5-10 percent zinc anodes, they have to be embedded in a suitable material which will prevent polarization and ensure maximum efficiency. A mixture of slaked lime containing sodium chloride has been found suitable and the addition of a mercury salt (e.g., calomel) is advantageous. The work of installing the aluminum anodes can be simplified by using pre-packaged anodes, i.e., aluminum anodes embedded in a water-permeable electrochemically active cement. Magnesium oxychloride cement has proved satisfactory for this purpose. The cement is made by adding a saturated solution of magnesium chlo-

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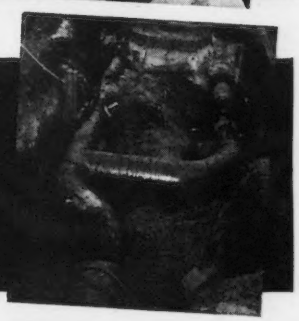

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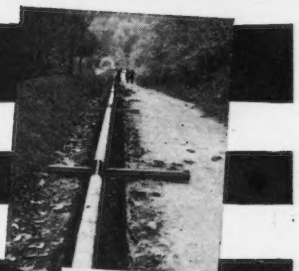

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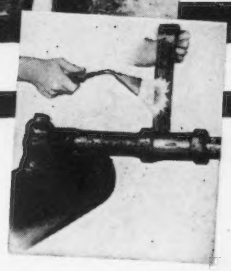

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ride to a mixture of equal parts of magnesium oxide and sand until a paste is formed which is poured around the aluminum anodes. The addition of a mercury salt to the cement is again advantageous.—ALL.

5.2.2, 7.2, 8.9.3

Cathodic Protection of Line. G. L. Doremus. Cathodic Protection Service. *World Oil*, **131,** No. 6, 206 (1950) Nov.

The cathodic protection system employing one magnesium anode at each end of the line and designed to last 10 years for the Marine Gathering Company 8-inch gas line to Pure Oil Co. Rollover drilling platform in the Gulf of Mexico is described.

5.2.1, 8.9.5

Marine Applications of Cathodic Protection and the Electrocoating Process. H. S. Preiser and B. L. Silverstein. *J. Am. Soc. Naval Eng.*, **62,** 881-905 (1950) Nov.

The history and development of marine electrocoating, its successful applications to stationary marine structures, and in derusting and descaling (at high current densities) and the possibility of extending cathodic protection and electrocoating techniques to preserving the hulls of active ships in the Navy are covered.

5.2.2, 8.4.3, 2.3.5

Discussion on "Cathodic Protection of Fourteen Offshore Drilling Platforms." F. L. LaQue. *Corrosion*, **6,** No. 9, 317-318 (1950) Sept.

It is suggested that high purity zinc would be more suitable than fragile calomel half-cells for checking the potential of structures immersed in sea-water. The zinc potential is not significantly affected by small changes in the composition of sea-water and there is the further advantage over calomel, that the potentials to be measured can be accommodated on the available portable potentiometers.—ZDA.

5.2.3, 4.6.6, 7.5.4

A Study of Some Metals for Use as Permanent Anodes in Water-Tank Cathodic Protection Systems. A. L. Kimmel. *Corrosion* (Technical Section), **6,** 353-358 (1950) Nov.

Since, in water-tank protection systems, ideal conditions do not exist, Faraday's law cannot be used to calculate rate of dissolution of metal. Therefore experimnets were made on various commercial metals and alloys used as anodes. These were 99.99 percent aluminum, 3S aluminum, hot-rolled black iron, commercial nickel Monel, Inconel and Types 302 and 316 stainless steel. Data are tabulated, charted and discussed.—BLR.

5.3 Metallic Coatings

5.3.2

Sprayed Metal Coatings for Corrosion Protection. G. Tolley. *Metal Finishing*, **48,** No. 10, 69-72 (1950) Oct.

Discussion of zinc, cadmium, aluminum and other metallic coatings as protection against corrosion.—INCO.

5.3.2, 5.9.4

New Platings Resist Corrosion. J. Lomas. *Machinery Lloyd*, **22,** No. 7, 91-93 (1950).

Rhenium has been successfully electrodeposited on an experimental scale, tantalum has also been electroplated, but efforts made to develop the process on a commercial scale have not yet been successful. Electron-diffraction studies of the structure of stainless steel surfaces show that a solid solution ($Ni,FeCrO_4$) is formed on the surface and protects the underlying layers without flaking off. Aluminum surfaces too big to be dipped or sprayed are given smooth protective coatings, equal in performance to electrolytic coatings, by brushing with two coating chemicals. A tin-zinc electrodeposited coating can be employed as an alternative to cadmium, particularly for electrical parts. If nickel or cobalt is electrodeposited simultaneously with tungsten, a coating with up to 50 percent tungsten, which could be used for rebuilding parts subjected to high temperature, can be obtained.—MA.

5.3.4

Galvanizing by the Sendzimir Process. K. Oganowski. *Products Finishing*, **14,** No. 11, 42-44+ (1950).

In this process the surface of the base metal is first oxidized and the oxide then reduced. The oxidation may be achieved by heating in an oxidizing medium or by other chemical means, and the reduction is carried out in a furnace having a suitable atmosphere. Some details are presented of the conditions required, but full information is not given. Information is also presented on the galvanizing-bath and other equipment used.—MA.

5.3.2, 4.4.2, 4.6.11, 5.9.1

Surface Quality of Hard Chromium Plated Parts. W. Eilender, H. Arend, and H. W. Dettner. *Metalloberflache*, **4,** No. 5, A69-A71 (1950).

Experimental study of influence of hard chromium plating upon surface quality with the basis metal (various steels) being prepared by electrolytic polishing, machine grinding, or hand polishing. Methods of evaluating surface roughness. Relationship between roughness of basis metal and roughness of hard chromium deposit. Corrosion resistance (25 percent formic acid; synthetic seawater) of hard chromium plates deposited on basic metals of different roughnesses. Conclusions to be drawn for purposes of practice, in particular with respect to the use of electro-polishing of surfaces to be hard chromium plated. Translation available Henry Brutcher, Box 157, Altadena, Calif.

5.3.2, 4.1, 5.3.4

The Protective Value of Zinc Coatings. *Engineering & Chemical Digest*, **2,** 236-241 (1950) July. (Condensed from zinc Develop. Assoc. Tech. Memo. No. 11.)

Tells how zinc and zinc-coated iron behave on atmospheric exposure and how zinc coatings protect iron and steel. Discusses need for uniformity of thickness, effects of iron in zinc coatings, "white rust" (basic zinc carbonate) and its formation, various ways to apply zinc coatings and recommended thicknesses.—BLR.

5.3.2, 7.5.5, 4.6.6

Metallizing Make an Old Water Tank Like New. J. E. Wakefield. *Engng. News-Record* (U.S.A.), **145,** 40-41 (1950) July 6.

A description of the treatment given to a badly corroded 65,000 gallon water tank. The tank was cleaned, and pits were filled in by arc welding. After grit blasting the whole interior surface of the tank was coated with a minimum of 0.008-in of sprayed zinc. 1400 lb of zinc were used. Zinc coatings on two other water tanks are quoted as having given excellent service, even at the water line. 2 Figs. 1 Table.—ZDA.

5.3.2, 2.3.7, 5.3.4

Spotlighting Finishing Progress. Allen G. Gray. *Products Finishing*, **15,** 44+ (1950) Oct.

Reviews recent work on: corrosion of composite electro-plated coatings (separate papers by J. E. Stareck, W. A. Esley, and H. A. Pray); adherence tester for organic finishes (C. J. Rolle and T. L. Dietrich); and palladium plating baths for heavy deposits (E. M. Wise and R. F. Vines).—BLR.

5.3.4, 5.3.2

Influence of Various Additions to the Hard-Chromium Plating Bath on Character of the Chromium Layer. (In Czech.) *J. Doskar. Hutnicke Listy*, **5,** 240-247 (1950) June.

Test results are tabulated, graphed, and illustrated. Value of certain additions is demonstrated.—BLR.

5.3.4, 5.9.1, 1.6

Metal Finishing Guidebook-Directory 1950. 19th Annual edition. 8 x 5¼ in. Pp. 488, illustrated. (1950). New York: Finishing Publications Inc., 11 West 42nd Street. 18 ($2.50.)

This annual publication is a comprehensive compendium of information mostly on electroplating but also dealing with the finishing of aluminum and magnesium alloys and metal coloring. There are over 70 articles, mostly by different authors who are well known in their own fields, covering the general subjects of plant, polishing, cleaning and pickling, plating solutions, analysis and testing and special surface treatments. In addition, there are tables of data and a Directory Section (mainly of interest to American readers). A few of the articles are documented, enabling the reader to check the information given or to obtain more and there is a list of selected reference books on electrodeposition and metal finishing.—MA.

5.3.4

Metal Spraying Pays Off as **"Finishing Tool."** *Steel*, **127,** 79-80, 82 (1950) Aug. 28.

Discusses conditions governing type of coating needed. Considers paint vehicles, long-term protection, industrial versus mild atmospheres, fresh water versus sea water, and corrosion at elevated temperatures. Describes sealing and finishing of sprayed metal. Involves aluminum and zinc coatings.

5.3.4, 5.9.1, 6.4.2

Electrodeposition on Aluminum. Johannes Fischer. *Metalloberflache*, *B*, 1, No. 11, 117-121; No. 12, 134-136 (1949).

A survey of the literature on the following stages in the electroplating of aluminum: 1) cleaning and degreasing; 2) preliminary surface treatments—mechanical roughening, chemical and electrochemical pickling, anodic oxidation—designed to ensure good adhesion of the coatings; 3) the plating process itself; nickel adheres better than any other metal; suitable bath compositions and operating conditions for the deposition of this metal are, therefore, discussed in

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some detail; 4) heat-treatment of the coatings; 5) chromium plating with or without the use of intermediate deposits, i.e. whether for decorative purposes (thin coatings) or wear-resistance (thick coatings), respectively; 6) precautions necessary when plating aluminum alloys; and 7) testing the finished coatings. 48 references to technical literature and to patents.—MA.

5.3.4, 5.3.2, 6.4.2, 5.9.3

Chromium Is Plated Directly on Aluminum by New Process. T. C. Du Mond. *Materials & Methods,* **32,** No. 4, 56-57 (1950) Oct.

A new process for plating chromium directly onto wrought, sand cast and die cast aluminum alloys has been developed by Cro-Plate, Inc. The aluminum part is wet blasted by quartz crystal suspended in water to remove the oxide film. A coating of the chemically inert abrasive remains on the aluminum surface to prevent any action by air before being placed in an acid plating bath where the coating drops harmlessly to the bottom of the tank. The mechanical cleaning process increases the surface area of the part by about ten times and adds to the bonding action between the chromium and base metal. The chromium coatings, which can be deposited on aluminum at a rate of 0.007 to 0.008-in. per hour, have a hardness of between 75 and 82 Rockwell C. Chromium-plated aluminum is more wear resistant than unclad aluminum, it has an impact value near that of unplated mild steel and surface friction is reduced. The combination of light weight and wear resistance found in chromium-plated aluminum makes it useful for aircraft applications such as gears, ring seals and for ball bearings, pulleys and balls used in machine gun mounts. The same process can be used with any of the other commonly used plating metals to plate any base metal with the exception of magnesium.—ALL.

5.3.4

Metal Spraying Using the (Wire) Pistol. W. F. Hedde. *Rev. gen. Mecan.,* (N.S.), **34,** No. 19, 282-284 (1950).

A survey of the history, technique, and industrial applications of zinc, aluminum, lead, copper, brass and tin spraying, using the wire pistol. Some details are also given of the use of the process for decoration and the reclamation of worn parts.—MA.

5.3.4, 3.5.5

Intrinsic Porosity. *Electroplating and Metal Finishing,* **3,** 487-490 (1950) Sept.

Intrinsic porosity is an extremely fine form of porosity. Such fine pores are damaging to an electrodeposit, because they are invariably filled with chemicals from the plating solution which accelerate corrosion. Explains why such pores are inevitable in an extremely thin electrodeposit and discusses the possibilities of eliminating them from electrodeposits of commercial thickness. (To be continued.)—BLR.

5.3.4, 5.3.2, 6.3.19, 2.3.2

Electroplate Finishes on Zinc-Base Die-Castings. E. E. Halls. *Metal Treatment,* **15,** No. 56, 209-216 (1948-1949).

Halls gives results of corrosion tests, severe humidity and salt spray, on zinc-base die-castings plated with nickel, chromium, brass and cadmium. The most suitable coatings were found to be either nickel plated directly or nickel plated on to a copper deposit. A suitable bath for plating nickel directly on the casting is given. Thin brass and cadmium coatings gave little or no protection against corrosion. Halls emphasizes that to obtain good electrodeposits it is essential to have sound castings with good surfaces and that the casting should be designed for plating.—MA.

5.4 Non-Metallic Coatings

5.4.2, 4.4.2

Effects of Acid Treatment on Abrasion and Acid Resistance of Porcelain Enamels. W. N. Harrison, J. C. Richmond, and J. R. Crandall. Nat. Bur. Standards (U.S.), *Tech. News Bull.,* No. 33, 98-99 (1949) Aug.; condensed in *Refrig. Eng.* **57,** 645 (1949) July.

Tests made on enameled graduates for darkroom use indicated that acetic acid was much less corrosive than were hydrochloric and nitric acids. Treatment of the enameled surface with acetic acid, which produced only minor visible attack, did however strongly inhibit further attack when subsequently treated with citric acid. The citric acid severely attacked the untreated areas of the same enameled specimens. Treatment with butyric acid produced the same effect. The passivation effect may be explained by the hypothesis that the acetic and butyric acid preferentially leach alkalies from the enamel surface, leaving behind a silica-rich film that is resistant to further solution even in citric or stronger acids. Treatment for 15 minutes in 10 percent citric acid appreciably reduced the abrasion resistance of certain enamels having Class B or Class A acid resistance (PEI standard test), this effect being more pronounced on titanium-type enamels than on antimony-type enamels. In no case was the abrasion resistance of Class AA enamels affected.—RA.

5.4.5

Flake Aluminum Paints. W. Van Wullen-Scholten. *Fette u. Seifen,* **52,** No. 3, 154-157 (1950); *Lack—u. Farben-Chem.,* **4,** No. 2/3, 47 (1950).

The durability and gloss-retention of aluminum flake paints were studied. Alkyds and a tung-oil varnish were found to be suitable media. Best results are obtained over a primer of red lead.—RPI.

5.4.7

New Method of Hot-Spraying Anti-Rust Bituminous Paints in Shipbuilding. B. Stecher. *Hansa,* **87,** 459 (1950); *J. Brit. Shipbuilding R. A.,* **5,** No. 6, 378 (1950).

Two new spraying processes for bituminous coatings are discussed; in one, hot molten paint is forced through the nozzle of the gun, and in the other, material in wire form is used. Both methods use hot air for directing the paint to the surface. Traces of moisture which may still be present on the metal will therefore evaporate before the protective film is formed, so that it adheres firmly. The paint film produced is much thinner than that obtained by brush application of the molten material (0.04 instead of 0.08 in.), so that the new processes save up to 50 percent in material. The "wire method" is particularly useful for coating corners and angles which are difficult to reach.—RPI.

5.4.5

Some Aspects of the Protection of Iron and Steel Against Corrosion. U. R. Evans. *J. Oil Colour Chemists Assoc.,* 33, No. 359, 239 (1950).

The theory of corrosion is outlined and the type of primers which are most effective in its suppression are discussed. It is stressed that the primer must be applied to clean metal.—RPI.

5.4.5, 7.6.4

Coating the Interior of Boilers and Tenders. E. H. Heidel. Chicago, Milwaukee, St. Paul & Pacific R.R. Paper before Master Boilermakers' Assoc., 33rd Ann. Mtg., Chicago, Ill. Sept. 18-20, 1950. *Ry. Mech. and Elect Eng.,* **124,** No. 11, 666-667 (1950) Nov.

History of the use of coatings to prevent pitting in the interior of boilers and tenders is given. Requirements and advantages of boiler coatings, preparation of surfaces, interior of tenders and providing proper ventilation are discussed.—INCO.

5.4.3, 6.4.2

New Finish Gives Aluminum Good Wear-Resistance. Charles F. Burrows. *Iron Age,* **166,** No. 8, 73-75 (1950).

The new Martin or MHC finish gives a scratch- and wear-resistance to aluminum, which makes it suitable for many applications previously restricted to steel alloys. The finish is applied to aluminum or to aluminum alloys containing less than 5 percent copper in either the wrought or cast form by an electrochemical process giving a non-metallic file-hard, highly heat-refractive surface integral with the base metal. Finish is resistant to atmospheric and salt water corrosion.

5.4.5, 5.4.2, 5.9.4

Which Coating for Gray Iron. C. O. Burgess. Iron Founders' Soc. *Product Eng.,* **21,** No. 10, 103-110 (1950) Oct.

The author discusses organic finishes including special texture finishes, corrosion inhibiting primers, complete finishing system, special synthetic resins, asphalt or pitch-base enamels, japans and aluminum paint. Vitreous or porcelain enamels and chemical conversion coatings, oxide and phosphate are also outlined.—INCO.

5.4.5

New Rust Inhibitors. *Ordnance,* 35, No. 182, 134 (1950) Sept.-Oct.

Two rust-inhibitive white-lead pigments, non-reactive toward materials containing free carboxyl groups, have been introduced to the paint and varnish industry. Monsanto Chemical Co. is producing commercial quantities of trilead orthophosphate and dilead pyrophosphate, the few rust-inhibitive materials which are nonreactive with solution coatings composed of polyvinyl chloride-acetate copolymer modified with a dicarboxylic acid.—INCO.

5.4.5, 8.9.3

Maintenance Practices in a Small (Oil) Refinery (Use of Aluminum Paint). John S. Pfarr, Robert W. Pollard, Leon T. Harris, and William F. Dougherty. *Petroleum Engr.,* **22,** No. 7, C26-C30, C32, C34, C36 (1950).

Reference is made to the extensive use of aluminum paint.—MA.

5.4.5

Plastic Coated Steel Resist Corrosion. *Iron Age,* **169,** No. 26, 71 (1950) June 29. —MI.

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5.4.5, 8.9.5

Vinyl Protection for Ships' Hulls. *Brit. Plastics,* **23,** No. 255, 68-69 (1950) Aug.

Vinyl resins were used during the war to improve protection for the underside of naval craft against corrosion and fouling. This article describes Wash Primer No. 1, a Vinylite polyvinyl butyral resin, used as a pretreatment for ships' bottoms to insure adhesion of subsequent coatings. A complete underwater protective coating can be comprised of Wash Primer No. 1 and coatings based on Vinylite resins VAGH and VYHH. A steel panel coated with this combination exposed to sea water showed no sign of corrosion or fouling after 24 months. After 34 months some fouling was evident, although metal protection was still complete. A similar panel, coated with conventional U. S. Navy Specification protectives, was exposed in temperate sea water for 18 months. Fouling occurred after two months' exposure and no protection was offered after six months, considerable corrosion having occurred.—TDD.

5.4.7, 7.2, 8.9.3

Internal Pipe-Coating Techniques—A Review of Recent Developments. J. K. Alfred. Shell Pipe Line Corp. Paper before Am. Petroleum Inst., 30th Ann. Mtg., Los Angeles, Nov. 9-17, 1950. *Oil & Gas J.,* **49,** No. 28, 266+ (1950) Nov. 16.

The 3 methods of combating internal corrosion by lining the pipe with protective coatings are plastic lining applied in place, cement lining applied in the mill or local plant and cement lining applied in place. Each method is discussed in detail followed by a list of advantages of the method.—INCO.

5.4.7

Preliminary Treatment of Iron Surfaces Before the Application of Varnish Coatings. H. Ketterl. *Metalloberlache,* **3,** No. 3, 72-73 (1949). *Chim. et Ind.,* **63,** No. 3, 274 (1950).

The varnish is applied to an iron surface previously cleaned and allowed to stand in a current of moist air to acquire a thin layer of rust. The coatings have excellent adhesion and flexibility.—RPI.

5.4.7

Spraying Paint with Steam. *Product Finishing,* **3,** No. 6, 44 (1950).

A practicable method of spraying paints using superheated steam instead of compressed air has been developed. The advantages are that, as the paint is effectively atomized, it is possible to use paints of lower volatile content and higher viscosity. Superior results are claimed and the cost compares favorably with the normal operation.—RPI.

5.4.8, 1.7, 2.3.6, 2.3.2

Formulation of Anti-Corrosive Compositions for Ships' Bottoms and Underwater Service on Steel. British Iron and Steel Research Assoc. Joint Technical Panel N/P2, 1st Report (1950) Jan. 26 pp.

A report of extensive raft and rotor tests on a series of anti-corrosive paints, comprising two principal media, a) phenol/formaldehyde/stand oil, b) coumarone/stand oil, and 25 principal pigmentations. Modifications of the principal media, incorporating tung oil, and also media based on chlorinated rubber and on dehydrated castor oil, were tested with 5 of the pigment mixtures. The chlorinated rubber paint gave the best results (reference is made, however, to difficulties in application). The most promising composition is the one based on phenol/formaldehyde/linseed and tung stand oils (oils in ratio 1:1) pigmented with basic lead sulfate and aluminum in the ratio 2:1. A method for preparing steel panels for test having a known and reproducible amount of mill-scale on the surface is described.—RPI.

5.4.8, 1.3, 3.3.2

Anti-Fouling Compositions. C. C. Downie. *Paint, Oil Col. J.,* **118,** No. 2706, 460-462 (1950).

A review of some U. S. literature.—RPI.

5.6 Packaging

5.6.3, 5.8.2

"Gas Attack" on Corrosion. *Prod. Finishing,* **3,** No. 4, 67-73 (1950); *J. Inst. of Metals,* **17,** Part II, 828 (1950) July.

An account of the use and properties of "vapor phase inhibitor" V.P.I. 260 for the prevention of metallic corrosion. Some test results are given and the material is stated to be especially useful for the corrosion protection of ferrous metals, aluminum, Duralumin and chromium plate.—INCO.

5.6.3, 5.4.5

Latex Films as Temporary Protective Coatings for Metal Surfaces. J. A. Taylor. *Rubber Developments,* **3,** No. 2, 39-40 (1950); *Verfkroniek,* **23,** No. 6, 163 (1950).

The use of rubber films is described for the protection of metal parts during transit and storage. A protective latex of the pre-vulcanized or vulcanizable type, containing sodium benzoate and/or sodium nitrite corrosion inhibitors is recommended. The methods of applying the coating are described.—MA.

5.7 Treatment of Medium

5.7.4

Gear Case Moisture Control. *Journal, The British Shipbuilding Research Association,* **5,** Abstract No. 4125 (1950) Oct.

An article in Marine News described the Marine Control Company's Dehydrator and Reactivator which, although designed for another purpose, has been used for drying the air in sumps and marine reduction-gear cases. The drying agent is silica gel. The first unit was fitted in the gear case of the tanker Mobilight, and, after a year's service, there was no evidence of corrosion or rust. Moreover, despite the coating of oil on its surface, the silica gel had lost very little of its effectiveness. The unit occupies a little more than 13 cubic feet of space.—TIME.

5.8 Inhibitors and Passivators

5.8.2

Nakcro Corrosion Inhibitors. *Electroplating,* **3,** No. 15, 582 (1950) Nov.

Nakcro I is a water-soluble corrosion inhibitor. It is used when metals are treated by wet processes to prevent after-rusting. It does not affect subsequent painting, galvanizing or anodizing. It is claimed to protect degreased bright metals stored or shipped for long periods. This material may prove a useful addition to after-pickling rinses to prevent rusting and staining before plating, and in the after-plating rinse, to add to the corrosion resistance of the finish and to prevent staining and rusting during storage. Nakcro II is an inhibited grinding coolant claimed to be stable over long periods.—INCO.

5.8.2, 5.9.2, 7.6.4

Anthracene-Oil Bases as Inhibitors for Use in Chemical Removal of Boiler Scale. (In Russian.) N. A. Gruzdeva. *Promyshlennaya Energetika* (Industrial Power), **7,** 14-16 (1950) June.

Physical characteristics of above bases were determined. Comparative data on anthracene bases vs. other common inhibitors are tabulated.—BLR.

5.8.2, 4.4.2

Water-Soluble Cutting Oils as Pickling Inhibitors. K. F. Hager and M. Rosenthal. Dept. of the Army., Gen. Elec. Co. *Oil Gas J.,* **49,** No. 16, 142-143+ (1950) Aug. 24.

Cutting oils were found to be inhibitors against acid attack of the base metal. They give a temporary protection against re-rusting to the freshly pickled surface. The experimental procedure and results of the determination of the degree of retardation of acid attack on mild steel S.A.E. 1010 are given. Increasing the concentration of cutting oil increases the retardation if the retardation in lower concentrations is sufficiently low. The effectiveness of the inhibitor is not injured with increase in pickling time. H 136 exhibited retardations over 83 percent when added to 5 percent sulfuric acid (0.01 percent by volume). The addition of 0.02 percent of this compound to leaded or white gasoline containing 3 percent sodium chloride water solution prevents corrosion on iron and steel. The H 136 protects metals against corrosion by the formation of an adherent monomolecular film.—INCO.

5.8.2, 8.4.3

Organic Corrosion Preventive. Charles M. Blair, Jr. *World Oil,* 131, 159-160+ (1950) Nov.

Results of using organic corrosion preventives in oil and gas wells are reported. Describes the various types of inhibitors and their specific applications. Methods of introducing the chemicals into the well are also discussed. Typical case histories are presented.—BLR.

5.8.2, 4.6.4

A New Method for the Protection of Metals Against Pitting, Tuberculation and General Corrosion. H. L. Kahler and C. George. W. H. & L. D. Betz. *Corrosion,* **6,** No. 10, 331-340 (1950) Oct.

This paper presents a new principle in the field of corrosion for the control of tuberculation and pitting of metals in waterside corrosion. It is termed the dianodic method and employs a dual treatment of molecularly-dehydrated phosphates and chromates over selective pH ranges. Its use in relatively low concentrations gives benefits not obtainable with single treatments such as chromate, phosphate, etc., at considerably higher concentrations. From experimental evidence it appears that the two anodic

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treatments used together under the conditions of the dianodic method are not acting as two separate treatments but as a new single agency for the elimination of pitting and tuberculation. Pit reductions of 80-90 percent are not unusual with this method. Quantitative pit data are presented on specially-surfaced high carbon steel corrosion specimens accompanied by tuberculation data on the threads of pipe nipples. Plant results in recirculating cooling water systems so far indicate complete accord with the experimental data presented.—INCO.

5.9 Surface Treatment

5.9.1

Surface Preparation — Preparation of Metals for Organic Finishes. A. Douty. *Org. Finishing* (U.S.A.), **11,** No. 9, 16-21+ (1950) Sept.

The preparation of metals for organic finishes is necessary to promote immediate adhesion, to retard underfilm reactions and to prevent substances from entering the film which would impair protection or decorative properties. Surface treatments may be designed to clean or to produce corrosion-retarding and paint-holding coatings. The selection of a suitable procedure depends upon: 1) the kind and surface conditions of the metal; 2) type of exposure to be expected; 3) grade of finish required; 4) type of organic finish to be applied. Metals may be cleaned by mechanical or chemical means. The various chemical methods of cleaning metals which include solvent rinsing, emulsifiable solvent washing, vapor degreasing, alkali cleaning, alkali cleaning with emulsified or suspended solvent and acid cleaning are reviewed. Natural oxide films and sealing should be removed before painting. Chemical methods are the simplest and most economical for removing oxide and the use of sulfuric and hydrochloric acids is sufficient with most metals. Cleaning processes are usually followed by chemical or electrochemical treatments which produce coatings consisting of more or less hydrated metal oxides or of metal salts. Paint preservative coatings should be applied where corrosive conditions will be experienced. Satisfactory coatings may be produced by immersion in hot alkaline sodium chromate solutions, by hot zinc phosphate solutions containing double fluorides or warm solutions containing phosphoric chromic and hydrofluoric acid in certain pH and concentration ranges. Oxide coatings on aluminum may be produced electrically with electrolytes of chromic acid, sulphuric acid, oxalic acid, sulfamic acid, phosphoric acid or boric acid. Dilute chromic acid is the favored choice of electrolytes for producing paint base oxide films.

The most widely used chemical treatment for magnesium prior to painting consists of acid pickling with either nitric-chromic acid mixture or with hydrofluoric acid and then sealing by boiling for 45 minutes or more in dichromate solutions. Magnesium may also be anodized but anodizing in an alkaline solution must be followed by dichromate sealing before painting. Special treatments for steel, cast iron, copper and brass are also described.

5.9.2

Continuous Strip Pickling. D. Brownlie. *Canadian Metals.* **13,** No. 3, 14+ (1950) Mar.

A description of modern practice in this field. In the continuous cascade system, the acid runs through four baths decreasing in strength from 23-26 percent to 9-11 percent before being discarded; the weaker baths remove most of the heavy loose scale, and the stronger baths complete the pickling process. The author also discusses pickling speeds and tank construction. Tanks are usually of steel with rubber and brick linings and are emptied by lead syphons or by a side discharge overflow arrangement. Sulfuric is the cheapest pickling acid, and is used at from 190°-210° F. In addition, there are notes on inhibitors, acid consumption, rinsing, drying and recoiling. —ZDA.

5.9.2, 5.3.4

The Bullard-Dunn Electrolytic Descaling and Tin-Plating Process. *Tin and Its Uses,* **21,** 3-4 (1949); also *Wire Ind.,* **17,** No. 194, 115 (1950).

A description of the operation, control, and advantages of the Bullard-Dunn electrolytic descaling and tinplating process for steel surfaces. Using a high current density the work is cathodically treated in a dilute sulfuric acid solution containnig tin as inhibitor. The tin deposits as soon as the scale or oxide is removed and is claimed to provide an excellent base for subsequent paints.—MA.

5.9.2

Development and Evaluation of Paint Removers Used by the U.S.A.F. C. W. Douglass. PB. 97658, 1948, 61 pp.

Many ingredients were tested and results recorded. Basic tests were made in response to a need for a paint remover for removing camouflage paints from aircraft surfaces and with the view to improving the existing U. S. Air Force Specification 14119-A.—BNF.

5.9.2

Pickling Tanks, Modern Developments in Construction. (Vasche di decapaggio). *Iron & Steel,* **23,** No. 4, 116-120 (1950) Apr.—MI.

5.9.3, 2.4.3, 5.3.4

Surface Treatment and Test Methods. (Bearbeitungs — und Messverfahren der Oberflaechentechnik) (in German). J. Eckert. V.D.I., **1950,** 520-521, July.

The Industrial Exposition, Hanover 1950, featured a series of surface-finishing machines that were distinguished by their high quantitative controllability. Outstanding among these were a gear buffer and a roller burnishing machine. An improved Forster-Leitz roughness meter showed a power of resolution of $\pm$ 0.05μ. An automatic Rockwell hardness tester handles 900 specimens per hr. A new hardness tester employs the relation between hardness and magnetic coercivity. In the field of coatings, the method of spraying hot metal onto a base has been extended to plastics. Nondestructive surface testers on electro-optical and magnetic principles show great promise in mass-production technique.—TDD.

5.9.3

Mechanical Scaling of Low Carbon Steel Rods. J. Peignier. Societe Metallurgique de Gorcy. *Wire and Wire Products,* **25,** No. 8, 649-650, 693-694 (1950) Aug.

Mechanical scaling can be used for hot-rolled low carbon steel rods in place of chemical pickling. The article contains a description of the apparatus and the operation. The rod strands are subjected to deformation causing the scale to break away. The rod strands are then cleaned. In comparison, the two methods are both 99 percent efficient while mechanical scaling amounts to half the cost and has none of the disadvantages of pickling.—INCO.

5.9.3, 1.3

Polishing and Buffing. James H.Lindsey. *Plating,* **37,** 1143-1148 (1950) Nov.

Review covers articles and papers published during 1944-1948. Every effort was made to avoid modification of editing of the opinions expressed by the authors of these articles and papers. Manufacturers' literature is excluded.—BLR.

5.9.3

Barrel Finishing—I-VIII. *Product Finishing* (London), **2,** No. 2, 20-24 (1949); No. 3, 24-29, 38-43; No. 6, 46-54; No. 8, 44-51; No. 9, 36-48; No. 10, 48-55; **3,** No. 1, 82-88; No. 2, 90-96, 98 (1950).

I. Historical treatment and general introduction. II. A description of the plant, methods, and materials used for barrel-finishing plastic products. III. Deals with the types and uses of rumbling barrels for metal cleaning, derusting, phosphating, painting and polishing. IV. A detailed survey of barrel-polishing methods. V. An account of the American submerged-abrasive burnishing technique in which the processing drum or barrel and its contents are completely submerged and rotated in a lather of neutral soap and water. The equipment, type of abrasive (a form of processed aluminum oxide), function and types of soap and available data regarding methods of application are discussed. VI. A description and discussion of technical factors affecting the production of the max. efficiency from the submerged barrel-burnishing process. VII. Discusses further details of the most satisfactory procedures for submerged-abrasive burnishing. These include selection of the correct stone size, barrel speeds, and ratio of stone load to vol. of parts. VIII. Additional aspects of stone load, stone-to-part ratio and the importance of water level are considered.—MA.

5.9.3

Blast-Cleaning Metal Parts. *Ind. Finishing,* **26,** No. 9, 34-36 (1950).

An air-less centrifugal type of dry blast-cleaning equipment is used to prepare refrigerator parts for corrosion-resistant coatings.—RPI.

5.9.4

Salt-Bath Chromizing. *Iron Age,* 163, No. 21, 71-72 (1949) May 26.—MI.

5.9.4, 6.2.3

German Standard DIN 55700: Phosphating of Steel Parts for Corrosion Protection: Instructions. (In German.) Deutsche Normenausschuss. *Metalloberflache, Ausgabe A,* **4,** No. 9, A137-A140 (1950) Sept.

Covers the phosphating process, including pre-treatment, rinsing and after-treatment, and testing of parts. 18 different solutions (immersion, spray and electrolytic methods).—BNF.

6.2.2, 6.2.3, 6.2.4, 1.3

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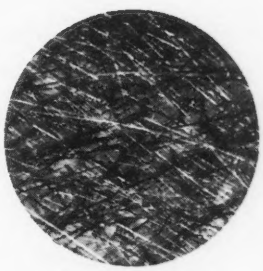

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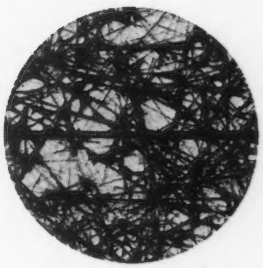

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Ind. Eng. Chem., **42**, 1986-1990 (1950) Oct.

Reviews literature on new developments of past year.—BLR.

5.9.4, 6.4.2

Coating Gives Corrosion Resistance to Aluminum Alloy Surfaces. *Die Castings*, **8**, No. 10, 65 (1950) Oct.

Lyfanite, a chemical, corrosion resistant type of coating, chemically deposited on aluminum alloy surfaces is made by the Neilson Chemical Co., of Detroit, Michigan. It provides a good base for paint and also as a protective coating where immediate painting is not performed or where corrosion resistance is desired for interior storage purposes. According to the company, salt spray, humidity, water immersion and adhesion tests have proved satisfactory.—ALL.

5.9.4, 6.4.2

Paint Adhesion on Aluminum. *Electroplating and Metal Finishing*, **3**, 465 (1950) Aug.

Describes chromate-permanganate pretreatment.—BLR.

5.9.4, 6.4.2

Recent Studies on the Anodic Oxidation of Aluminum and Its Alloys. J. Herenguel. *Revetement et Protection*, **3**, No. 10, 5-12 (1950).—EL.

5.9.4

Electrolytic Siliconization (Siliciuration) of Steels. M. Dodero and P. Blum. *Rev. Met.*, **97**, 544-546.

Review of siliconization by usual methods. Details of electrolytic method, with special reference to treatment of internal surface of armco iron crucible. Results of corrosion tests in 50 percent nitric acid are given.—INCO.

5.9.4, 5.3.4, 6.4.2

The Etching of Aluminum for Direct Plating With Other Metals. J. M. Bryan. *J. Electrodepositors' Tech. Soc.* (England), **26**, Advance Copy No. 11 (1950) Apr.

By means of a simple test, based on a solution of iodine, it has been possible to select, from a large number of etchants, one which is capable of bringing the surface of aluminum into the right conditions for direct plating with other metals. The solution found to give best results is of the following composition: 50 g. dextrin, 150 cc. water, trichloroacetic acid to 1 litre. The etchant is used at 95° C (203° F) for 1-2 minutes. Precise control of conditions for washing after etching is an essential feature of the process.

Details are given of the procedure which has been found to give best results for deposition of copper and nickel on etched aluminum, 1) by chemical displacement, and 2) by electrodeposition. For deposition of nickel by chemical displacement, the solution used is of the following composition: 250 g. nickel sulfate, 50 g. nickel chloride, 100 g. ammonium citrate, 3 g. perminal BX, and water to 1 litre. No plating is obtained in the absence of chloride from the above solution. For electrodeposition of nickel, a solution of the following type is recommended: 100 g. nickel sulfate, 50 g. ammonium sulfate, 2 g. boric acid, and water to 1 litre. The solution is agitated, and plating is continued for about 30 minutes at 50 amp./sq. ft. using a nickel anode. Deposition from the regular Watts-type solution also gave good deposits and the plating was more rapid, but there was a tendency to pitting.

The deposits produced by chemical displacement are of good appearance after polishing but are inevitably porous, since the current must necessarily be generated by aluminum passing into solution, which causes the rate of deposition to diminish gradually to zero before coverage is complete. Coatings obtained by electrodeposition, on the other hand appeared when examined under a binocular microscope to be free from pores.—ALL.

5.9.4, 6.2.4

Rapid Determination of Thickness and Continuity of Oxide Layers. (In French.) Carlo Sonnino. *Rev. Aluminum*, **27**, 283 (1950) July-Aug.

Briefly describes two rapid and simple methods for control of the anodizing treatment on aluminum.—BLR.

5.9.4, 6.4.2

Chemical Polishing of Aluminum and Its Alloys. (Le polissage chimique de l'aluminium et de ses alliages), J. Hérenguel and R. Segond. Société Francaise de Métallurgie. (France). Resumés des Communications—*Journees Metallurgiques d'Automne*, **1950**, 15-16, Oct. 16-21st.

A mixture of sulfuric and phosphoric acids with an oxidant, similar to that used in electrolytic polishing, can be used to polish light metals without the use of applied electric current. Formulae of this kind have been studied since 1926, but their use was not successful. From numerous studies made during the last few years successful formulae have been found. Commercial possibilities of the chemical polishing process are indicated and reference is made to one or two applications of the process in connection with micrography.—ALL.

8. INDUSTRIES

8.8 Group 8

8.8.1

High-Pressure Vessels in the Chemical Industry. J. J. Granville. *Institution of Mechanical Engineers, Proceedings*, **162**, No. 2, 199-204 (1950).

Deals with mechanical requirements for high-pressure vessels and traces progressive changes in their construction during the last 30 years. Stress distributions in the cylinder wall, suitable closure mechanisms, effects of temperature, chemical and physical attacks and provisions for stirring, heating and cooling are discussed, as well as control mechanisms and safety precautions.—BLR.

8.8.1, 5.3.2, 7.6.8

Ammonium Sulphate Plant at Port Kembla. *Chemistry & Ind.*, No. 34, 633 (1950) Aug. 26.

The process of manufacture of crystal ammonium sulfate is described. The scrubbing tower is a lead lined, mild steel cylinder. The acid solution of ammonium sulfate 3.4 sulfuric acid is sprayed by Monel sprays.—INCO.

8.8.1

Equipment for Chemical Industry at the Industrial Exposition, Hanover, 1950. *Apparate fur die chemische Industrie.* F. C. Meltzer; VDI (German) **1950**, 490-492, July.

The chemical equipment exhibited at Hanover 1950 gave evidence of the possibility to extend corrosion-proof construction even to very large and involved machinery. The basic method of corrosion-proofing large mixers and homogenizers consisted in plating. High-vacuum equipment for sublimation of metallic and organic coatings, previously

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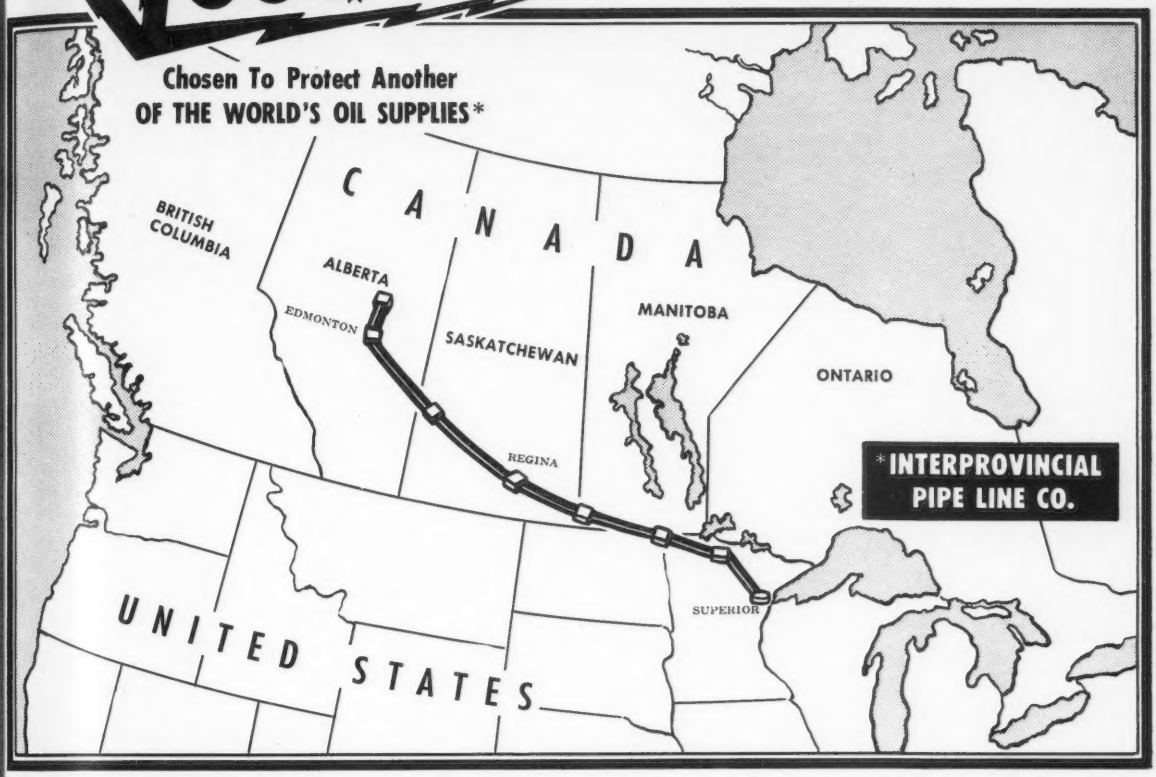

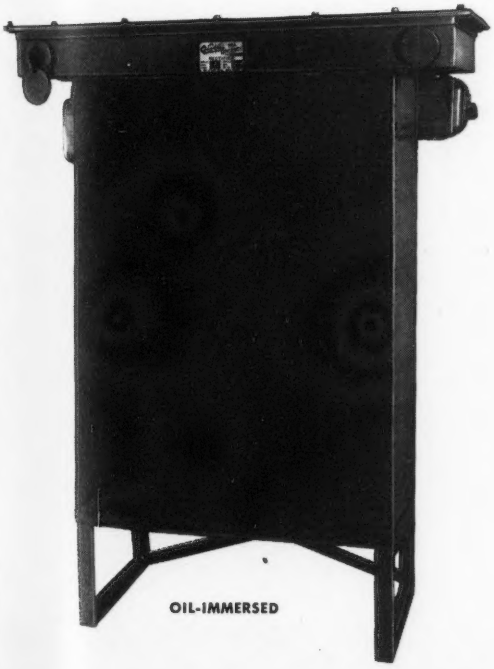

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only built on laboratory scale, is now available for industrial use. Several new air and water filters showed improved efficiency and durability over earlier types. A number of infrared chain driers have found increasing application in chemical industry.—TDD.

8.8.1

Organic Chlorination With HCl and Air. Robert M. Crawford. *Chem. Eng. Progress* (Engineering Section), **46,** 483-485 (1950) Oct.

Reviews literature. Describes commercial equipment.—BLR.

8.8

Unique Fertilizer Plant Claims Many Firsts. H. W. Van Ness. *Chem. Eng.*, **57,** No. 6, 102-105 (1950) June.

At the synthetic ammonia plant of Fertilizers & Chemicals, Travancore, Ltd., India, Type 304 stainless steel pipe linings are used in the ammonium sulfate crystallization process. Rubber and lead linings were easily corroded and the stainless linings lasted only 6 weeks. Rubberlined casings made in the U. S. were substituted and gave satisfactory service. Severe corrosion was found in the Type 304 stainless impellers of the pump and the bowls and conveyors of the continuous centrifuges. The conveyors were rebuilt with stainless steel weld metal or Stellite. Lime additions to the water supply have not stopped the corrosion in the steam boilers and cooling equipment.—INCO.

8.8

Sulfation of Fats and Oils. *Soap Perfumery & Cosmetics,* **23,** No. 4, 383-386 (1950). *Soap Sanit. Chemicals,* **26,** No. 6, 77, + (1950) June.

Monel equipment is used for the sulfation of animal and vegetable oils. It is used for linings, coils, agitators, pipe fittings, pumps and other equipment. In the sulfation of olive oil and tea seed oil, nickel-clad steel equipment is preferred because it gives a better color finished product. Nickel-clad equipment is preferred for storage of finished oils. When sulfuric acid concentration is about 80 percent, steel or iron reacting vessels are adequate. However, if through dilution, or by other means, the concentration falls below 80 percent, Monel equipment is required. Monel is common for washing and neutralization equipment. Alkyl sulfate bases are stored in Inconel equipment. Inconel is also used in spray drying some of the alkyl sulfates detergents, where color is an important factor. Monel is used commonly in the construction of solid or lined acid tanks, while Inconel was found more suitable in the more recently developed continuous fat splitting methods, which operate under pressure and use hot water.—INCO.

8.9 Group 9

8.9.1

Handbook for the Protection of Metal Aircraft Against Injurious Influences. Junkers Flugmotorenwerke. GDC. 17/312 T. Frames 1-20; Board of Trade, Tech. Inf. & Docs. Unit, FD. 2794/49.

An English version of the company's handbook on the protection of metal aircraft against corrosion by the use of paint, chemical layers, etc.—RPI.

8.9.1, 4.3.6, 5.8.2

Winterization of Airport Facilities. Corrosion of Aircraft by Calcium Chloride. Jerome Lederer. *Aero Digest,* **59,** No. 2, 49-51 (1949).

Sand is used in the winter at rainy airports to reduce slipping on ramps and runways. The sand is often treated with calcium chloride to keep it from forming into solid bunches and crusts in storage. The use of this calcium chloride gives rise to a corrosion problem, as the chloride is tracked into the aircraft or is driven against it by wind or propeller blast. Road tests show that this corrosion can be inhibited by the use of sodium dichromate (2 percent by weight), admixed with calcium chloride before application. Poly-phosphate-nitrite-nitrate mix also has been used as an inhibitor on roads, and is successful in preventing corrosion on steel (effect on aluminum was not evaluated).—MA.

8.9.1, 6.4.4

Corrosion Problems Arising from the Use of Magnesium Alloys in Service Aircraft. L. F. LeBrocq and H. G. Cole, RAE. *Metallurgia,* **42,** No. 251, 173-175 (1950) Sept.

Corrosion of magnesium alloys in service aircraft was studied. Four types of corrosion are described. contact corrosion with Duralumin in the presence of an electrolyte; corrosion in the presence of wood under damp storage conditions; corrosion of fuel tanks by wet leaded gasoline; and storage corrosion of welded assemblies in a 6 percent aluminum alloy. Methods of avoiding or inhibiting the corrosion are described for each of the four cases.—TDD.

8.9.1

Aircraft Metallic Materials Under Low Temperature Conditions. Maj. P. L. Teed. *Journal of the Royal Aeronautical Society,* **55,** No. 482, 61-83 (1951) Feb.

A recent session of the Royal Aeronautical Society was devoted to a consideration of the wide extremes of atmospheric conditions to which aircraft, civil or military, manned or unmanned, are subjected. These variations involve temperatures ranging from +194° to —130° F, pressures of from one atm to approximately one-tenth of that amount and a water content of from 2.5 percent by weight, in a very dense tropical cloud, to as low as 0.001 at stratospheric heigths. The extremes of temperature, pressure and moisture to which airplanes are subjected, either on the ground or in the upper air, results in interesting chemical or physical repercussions. These may include: greatly increased wear of commutators and their brushes; local corrosion of interior surfaces of air-conditioned pressurized aircraft; and decreased capacity, sometimes of large amount, in the resistance to tri-axial stresses of ferritic steels — including those of high corrosion resistance—as well as magnesium alloys, lead-tin solders and zinc die-casting alloys. Magnesium was found to rank next after ferritic steels among alloys whose impact resistance is adversely affected by decreases in temperature.—TDD.

8.9.3, 7.2, 5.4.5, 5.2.1

New Developments in Coatings and Cathodic Protection. C. L. Goodwin. Paper, A.P.I. Ann. Meet. Pipe Line Symp., Los Angeles, Nov. 14, 1950. *Pipe Line News,* **22,** No. 12, 32-34 (1950) Dec.; *Oil Gas J.,* **49,** 355-356+ (1950) Nov. 16.

Corrosion protection of pipe line systems is discussed regarding new developments in coatings, cathodic-protection developments, improvements in rectifiers, ground beds for rectifiers, improvement in galvanic anode installations, ground beds for lightning protection and other corrosion-control measures. Effective coatings supplemented with cathodic protection have been most successful in arresting and preventing corrosion losses.

8.9.1, 6.4.2

61S Alloy Tubing for Hydraulic Pressure Systems. G. A. Fairbairn and J. J. Sloan. No. Amer. Avia., Inc. *App. Hydraulics,* **3,** No 7, 24-26 (1950) Aug.

The widespread availability of 61S aluminum alloy tubing for industrial use has brought about its consideration for aircraft use. In doing so, the advantages of the alloy as a practical compromise between the relative weights of steel and aluminum, its superior corrosion resistance to that of 24S alloy, and its high workability are utilized. This alloy has been accepted by several aircraft companies for general use in all-aluminum-alloy tubing applications including hydraulics. In order to evaluate 61S material for use in 3000-psi hydraulic systems, samples of 61S-T6 tubing were subjected to burst pressure and pressure impulse tests. Tubing of ¼, 5/16, ⅜, ½ and ⅝-in. diameters was tested. The results of these tests indicated that the 61S-T6 tubing was suitable for use in 3000-psi hydraulic systems.—TDD.

8.9.4

Corrosion Problems in the Railroad Industry. R. McBrian and L. C. Atchison. Rio Grande Western R.R. Co.; Paper before NACE Conf., St. Louis, Mo, Apr. 4-7, 1950. *Corrosion,* **6,** No. 9, 286-289 (1950) Sept.

The paper deals with the specific problems of various types of motive power, track materials and passenger and freight cars. Abrasion corrosion, vibration-velocity corrosion, wear of Diesel locomotive surfaces, corrosion of corrosion resistant materials, corrosion due to climatic conditions and to refrigerator car ice-brine drainage are discussed. Illustrations.—INCO.

8.9

Chromating. H. H. Symonds, *Met. Ind.,* **76,** No. 25, 490 (1950) June 23.

An account of research into the cause of inconsistent results in the chromating of zinc alloy die castings. The trouble was traced to superficial corrosion of some of the castings. The faulty specimens could be recovered by the following treatment: trichlorethylene degreasing; immersion in boiling chromic acid solution; cold water rinsing with brushing; five minute immersion in boiling four percent sodium triphosphate solution; rinsing; 15 seconds immersion in 0.05 percent sulfuric acid; rinsing; 10 seconds immersion in cold chromating solution followed by washing and drying.—ZDA.

8.9, 5.4

Economy of Ships' Paints. *Ship. World,* **122,** 183 (1950); *J. Brit. Shipbuilding R. A.,* **5,** No. 4, 244 (1950).

The factors influencing the choice of a basic policy of ships' painting in any particular class of vessel are discussed. —RPI.

8.9, 5.2, 5.4

Underground Corrosion of Pipelines. *Times Rev. Ind.*, **4**, No. 41, 20-22 (1950) June.

This article draws attention to the seriousness of the problem of corrosion of pipelines, which is particularly severe in neutral waterlogged clay soils. The protection afforded by bitumen and other coatings may be reinforced by cathodic protection using anodes of magnesium, aluminum and zinc. The review contains 16 references to more detailed literature. —ZDA.

8.9.3, 2.3.5, 7.2

Surveying Pipe Lines for Reconditioning Data Using Surface Potentials. J. R. Cowles, Oklahoma Natural Gas Co. *Oil Gas J.*, 49, No. 20, 270 (1950) Sept. 21.

Surface-potential surveys afford a reliable method of determining serious corrosion on bare and poorly coated pipe lines. While skill is required to interpret results in certain instances, the data are definite even to field men observing the work. Cost of equipment is moderate. To evaluate this procedure with respect to its own operation, Oklahoma Natural Gas Co. has surveyed sections of three different lines using various checks on results.—INCO.

8.9.4, 5.2.1

Your Corrosion Problems Can't be Solved on a Hit-and-Miss Basis. Pat. H. Miller. *Proc. Am. Gas Assoc.*, 493-496 (1949).

Brief reference is made to the cathode protection of underground pipe-lines.—MA.

8.9.3

Training Programme for Corrosion Technicians. J. R. Cowles. *Corrosion*, **6**, No. 8, 245-248 (1950) Aug.

It is suggested that specially trained technicians could free corrosion engineers to cover more pipelines at less expense than otherwise possible. Paper describes the training programme carried out by the Oklahoma Natural Gas Company.—BNF.

8.9, 4.6

Salt Water Corrosion of Ships. *Motor Ship*, **29**, 78 (1948) May.

Reviews the fundamental principles applied in modern shipbuilding practice to minimize corrosion damage and gives examples of the consequences when these precautions are not observed. Improperly coated areas which sometimes occur are not normally troublesome, since under a periodic repainting schedule, they eventually become adequately protected before any significant damage occurs. However, these areas serve as focal spots for corrosion when abnormal conditions, tending to accelerate the corrosion rate, arise. Probebly the most potent of these abnormal conditions is electrolysis caused by stray currents. Stray current corrosion is most likely to occur when insufficient attention is paid to the grounding of electrical equipment used aboard ship which is supplied with power from the shore. Ground cables should have an area of at least one million circular mils for each 1000 amperes current being supplied to the vessel from the dock. A typical satisfactory grounding system consists of three one-million circular mil cables attached to the ship, forward, amidship, and astern. Additional cables are run directly from the grounding point to the ship when the current load exceeds 3000 amperes, in order to maintain the proper area-current ratio. Ground cables are made no longer than necessary and checked at regular intervals to ensure maintenace of good electrical contact. A second type of accelerated hull corrosion may arise from a combination of circumstances involving the presence of mill scale on the hull plating in conjunction with inadequate paint protection. Under such conditions, galvanic corrosion will develop as a result of couples between the mill scale and exposed steel and between the mill scale and rivet heads or welds, unless the latter are definitely cathodic to the mill scale, which usually is not the case. —TIME.

8.10 Group 10

8.10, 4.6, 5.4

Magnesia from Sea Water—The Dolime Process at The Palliser Works, Hartlepool. H. W. Thorp and W. C. Gilpin. Paper before Soc. Chem. Ind., Chem. Eng. Group. *Fluid Handling*, No. 2 and 3, 17-20; 55-58 (1950) Jan., Feb. Disc. 57-58.

Detils are given of the composition of the sea water, the magnesian limestone and the chemistry of the process. This is followed by considerations of precipitation and settling. The filtration problems, and those of sea water intake and the materials of construction are also given. For sea water system, bitumen-coated cast iron is the material of choice for pipe lines from the point of view of corrosion. Where temporary runs of pipe are required, mild steel pipe suitably protected by bitumen coating can be used. Mild steel is used for open channels where scale deposition is likely to be serious. Storage tanks for sea water, doline cream or settled slurry as well as those used for sand filters, reaction and settling are made of reinforced concrete. A settling tank floor showed penetration which in places was deep enough to expose some of the reinforcing rods. It was suggested that this was due to insufficiently closely graded material used for the aggregate. In a settling tank which received a surface dressing of a rich cement/sand mixture, the cement had largely disappeared, leaving only a sandy surface Another tank used for storing settled slurry revealed distinct softness of the walls. These instances suggest porosity, absorption and possibly crystallization leading to surface disintegration and then further penetration.—INCO.

8.10.2, 7.10, 3.5.3

Steel Ladle Refractories. Part I. F. I. Cordwell. *Refractories Journal*, **26**, 415-424 (1950) Oct. Review of paper by E. Rousseau, *Chemie et Industrie*, **62**, Nos. 3-4.

Begins review of recent technical progress. Gives details of work on development of an immersion test for evaluation of ladle refractories before placing in service. Discusses destructive agencies acting on steelmaking-ladle linings, erosion and corrosion phenomena and their significance during ladle filling and teeming, pyroscopic resistance of the glaze, and adverse consequences of destruction of the ladle lining. Gives details of test procedure. Tabulates test results for a series of ladle refractories.—BLR.

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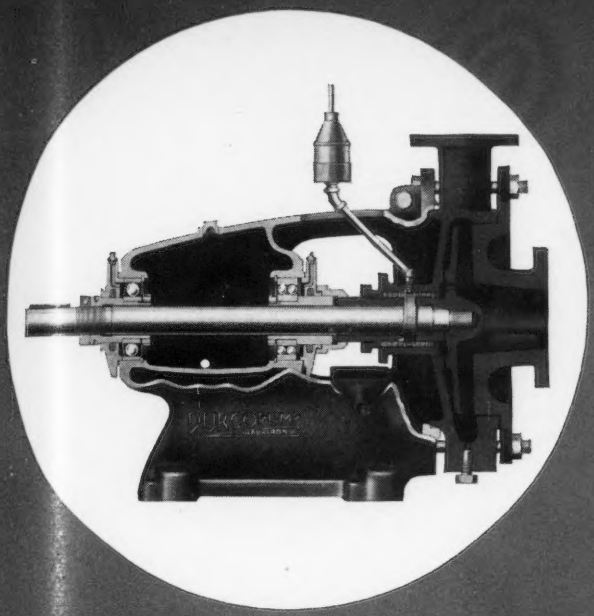

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